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SCHOOL CERTIFICATE GENERAL SCIENCE

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GENERAL SCIENCE

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Preface

THE authors' earlier book, *General Science*, was designed to provide a broad introductory course for all third form and fourth form pupils. As the name indicates, this volume contains all the additional topics which should be studied by those pupils who intend to sit General Science as one of their examination subjects.

As an appreciable number of these pupils will carry on with the study of one or more of the pure sciences in the sixth form, the standard of some sections of this book is slightly more advanced than is required for the School Certificate examination. Consequently, the amount of work that should be covered will depend upon the interests and abilities of the pupils. With some classes it should be possible to commence the work contained in this volume about the middle of the fourth form year, but in other cases teachers may prefer to leave this section of the work until the pupils enter the fifth form.

We are glad to have the opportunity of acknowledging our indebtedness to the following for their valuable criticisms and suggestions: Professors Elizabeth Gregory, H. D. Gordon and L. W. McCaskill; Doctors Muriel Bell and R. H. Thornton; Mrs Alison Stone, and Messrs R. S. Robbins, H. Maslen, G. J. Neale, H. L. Clarke, H. W. Sayers, C. C. Roberts, and J. B. Hepworth.

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I

The Flowering Plant

THE STRUCTURE and functions of the root, stem, leaf, and flower were studied in earlier work (*General Science*, page 177). It was found that the roots absorb water and soluble salts from the soil, and that these salts in solution pass through special channels called vascular bundles in the roots and stem to the leaves. In the leaves, by a process of photosynthesis, water from the soil and carbon dioxide from the air are manufactured into glucose which may be later converted to sugar, starch, protein, fats or oils and stored in the leaf, stem or roots. We are now going on to study the internal structure of plants.

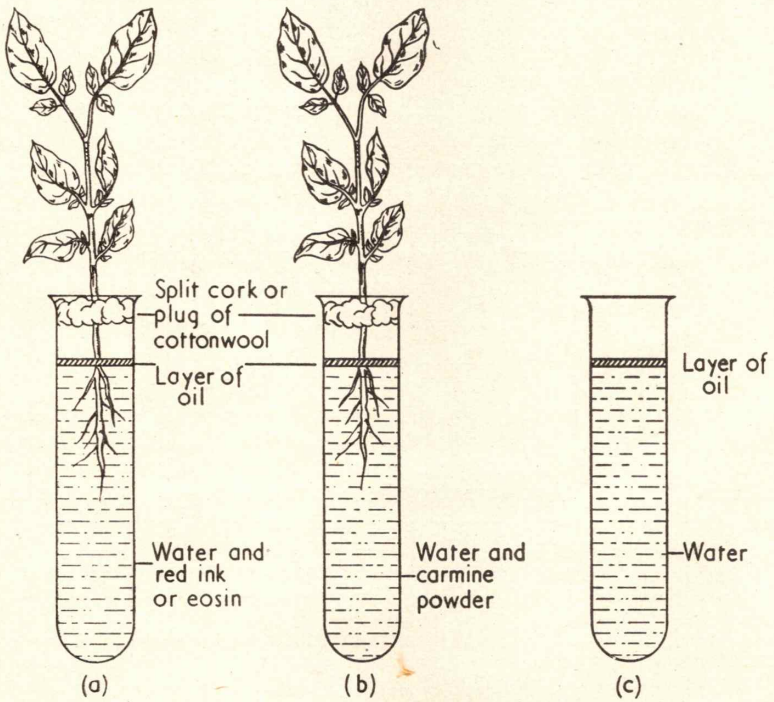

FIG. 1. Absorption of water and dissolved substances by plants.

THE ROOT

PRACTICAL WORK Carefully remove several weeds or garden plants from the ground and wash the soil from the roots. Set up three test-tubes as shown in Fig. 1—one with water mixed with red ink or eosin, one with water and carmine powder, and one with water only—and place the plants in two of them so that the roots dip into the liquid. Now add a small quantity of medicinal paraffin or olive oil to each test-tube. After a few days you will notice that the water level will have fallen in test-tubes (*a*) and (*b*), showing that roots have absorbed water. In test-tube (*c*) the water level will be constant as the layer of oil will prevent evaporation. Notice that the leaves of plant (*a*) have turned red, indicating that roots absorb solids in solution. The carmine powder is in suspension, and although the water level falls the leaves do not turn red.

From plant (*a*) cut thin cross sections of the roots with a very sharp wet razor blade.* Mount the sections in a drop of water or glycerine† on a glass slide and gently place on it a cover-slip. Examine the sections under the low and the high power of the microscope. Observe which cells are coloured red.

Water and solids in solution are absorbed by the root hairs and pass into the conducting cells or vascular bundles which are coloured red. These vascular bundles continue up into the stem and leaves. In a very young root the vascular bundles are arranged in three, four, five or six areas around the centre. In the older and thicker roots these bundles join up to form a star shape which may be three-, four-, five-, or six-pointed (*Fig. 2*). In very old and woody roots the star shape remains in the centre, but the conducting cells occupy a more or less continuous ring. Under the microscope you will probably notice that the walls of the conducting cells are much thicker than the surrounding cells which are called cortex. The water passes from the root hairs through the cortex to the conducting cells by osmosis [*Fig. 2 (d)*].

THE STEM

PRACTICAL WORK Cut very thin sections of the stem used in test-tube (*a*) of the root experiment or of a wallflower stem with a sharp wet razor blade. Stain the sections of the wallflower in aniline sulphate.‡ Mount several of the sections in water or glycerine and

*A wet razor blade makes the cutting of sections easier.

†Glycerine solution is used when mounting material because it evaporates very slowly. The solution is prepared by adding 10 cc of pure glycerine to 90 cc of water.

‡Aniline sulphate stains the cells in the stem so that they are more clearly differentiated. The stain is prepared by dissolving 1 g of aniline sulphate in 89 cc of 70 per cent alcohol and then adding 10 cc of N/10 sulphuric acid.

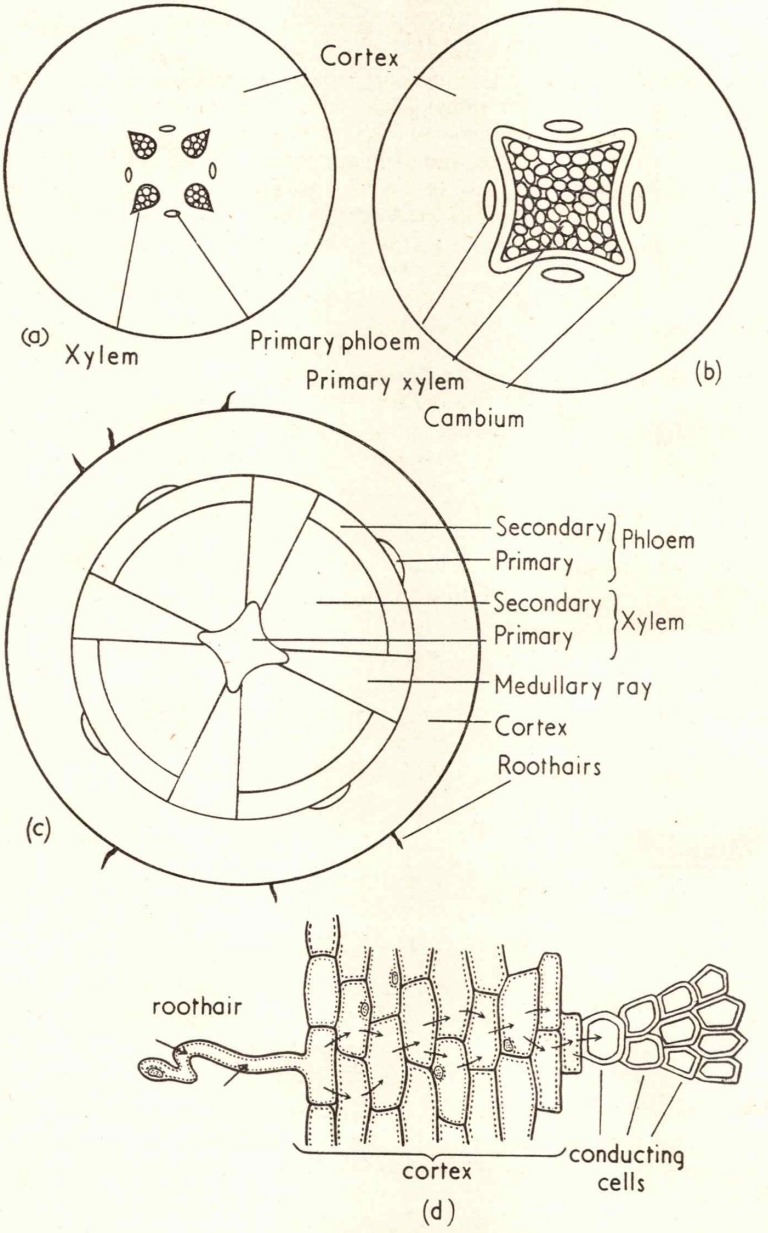

FIG. 2. Cross-sections of roots, showing distribution of vascular bundles: (a) Very young root; (b) Older root; (c) Very old root; (d) Path taken by water and substances in solution from root hairs to the conducting cells.

then examine them under the low and the high power of the microscope. You will notice some areas roughly oval in shape (*Fig. 3*) which are called vascular bundles. On closer examination, you will see that a vascular bundle consists of two main regions. The outer region is called the *phloem* and the inner region next to the pith is called the *xylem*. Between the phloem and xylem are thin-walled very small cells called the *cambium*.

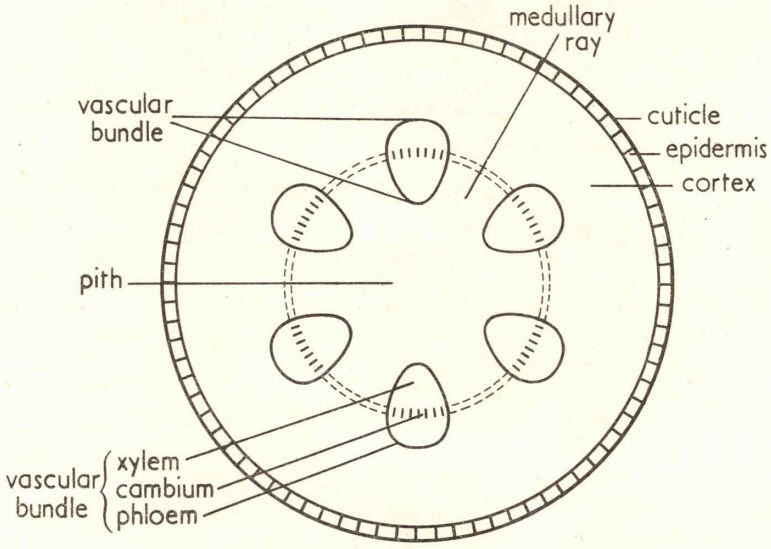

FIG. 3. Cross-section of the stem of a wallflower.

As the cambium is continually dividing, producing new phloem and xylem, the diameter of the tree will gradually increase. The cells in the phloem do not have thick walls like those of the xylem but are smaller and more regular than the surrounding cells of the cortex and the pith.

The xylem is made up of cells which have thick walls due to secondary deposition of *lignin*. Lignin is very hard and dense, and consists of a group of substances whose chemical composition is not known. The process of lignification, which is fairly complex, greatly stiffens the xylem and eventually it performs much the same function as the skeletons in animals. The xylem is made up of cells called *tracheids* and *vessels* which conduct the water to the leaves (*Fig. 4*). Tracheids and vessels are similar cells, in that they have heavily lignified walls. Tracheids are formed from a single cell, but vessels are composed of many smaller cells which have lost their end walls, forming very long cells up to one metre in length. The

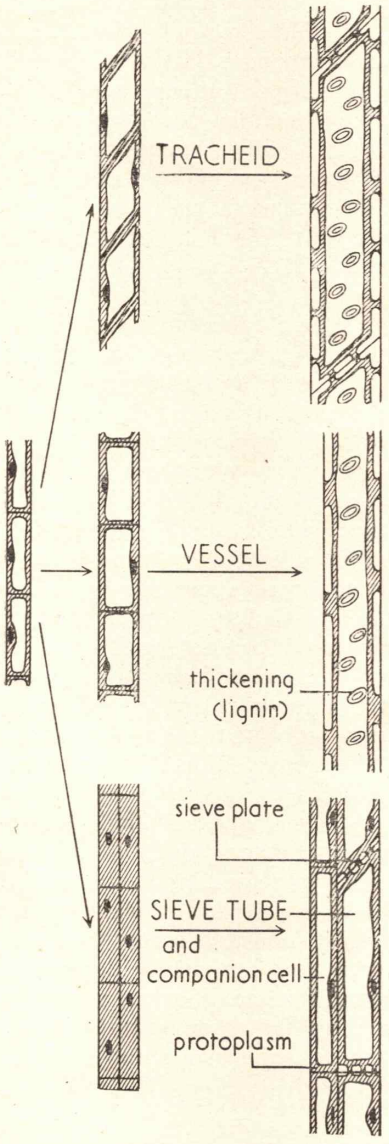

FIG. 4. Tracheids, vessels and sieve tubes.

bulk of the wood of a tree is xylem. The cells of the xylem nearer the centre are dead and no longer conduct water, but remain because of special thickening. The already lignified cells become filled with tannin which gives the wood a darker colour and preserves it from decay. This wood is referred to as heart wood.

As the cells of the phloem have no special thickening or lignification, the cellulose wall is soft. The important cells in the phloem are the *sieve tubes*, with perforated end walls or sieve plates, which serve for the conduction of manufactured foods. Although the phloem is being added to all the time it does not increase in thickness because these cells have no special thickening in the walls, and so are crushed and destroyed.

The xylem next to the cambium is active and conducts water through the vessels and tracheids, and this, together with the phloem, is called sap wood. When a tree is ring-barked* this sap wood comprising living conducting cells is destroyed, thus preventing the upward and downward movement of the sap.

Trees growing in regions where there are marked seasonal differences in weather—as of rainfall, sunshine, or snow—show clearly-defined annual rings. Thus in spring, when the trees' leaf-buds begin to shoot, there will be an increasing demand for water, and to meet this demand wide conducting cells are formed, giving the wood a lighter colour (*Plate 1*). In autumn the conducting cells are narrow and the wood assumes a darker colour. This difference between light and dark gives the appearance of a line which is called an *annual ring* (*Plate 1*). However, if the trees are not deciduous, or if there is no marked difference in seasons, there is no marked difference in the size of the conducting vessels so that the annual rings are more difficult to see.

The *pith*, the *medullary rays*, and the *cortex* all look the same when observed under the microscope, but are given different names according to where they are found in the plant (*Fig. 3*). They consist of soft living cells with no special thickening of sieve plates. The medullary rays transfer foodstuffs across the stem to the centre and so serve as a storehouse, particularly during the winter months. The greater portion of the stem of a very young plant, or a herbaceous plant such as a wallflower or nasturtium, is pith. The greater portion of the stem or trunk of a shrub or tree, such as rimu or totara, is dead xylem.

*When the bark and sappy wood of the tree are removed in the form of a ring round the trunk, the tree is said to be ring-barked.

THE LEAF

PRACTICAL WORK Cut a very thin cross section of a leaf and mount it in water or glycerine. To ensure thin sections, make a slit in a piece of hydrangea, fennel, or elder pith and insert a small piece of leaf in the slit. Cut sections of pith and leaf. The pith holds the leaf firm. The sections may be stained with a solution of aniline sulphate before mounting. Examine under the microscope with low and with high power (*Fig. 5*) and notice the vascular bundles or veins, which contain xylem, cambium, and phloem, just as the stem does. Notice that the other cells of the leaf are green because they contain *chlorophyll*, which is collected in small bodies called *chloroplasts*. The upper cells, or *palisade cells*, are more densely supplied with chloroplasts than the lower cells or spongy tissue. The *stomata* can be seen on the lower surface.

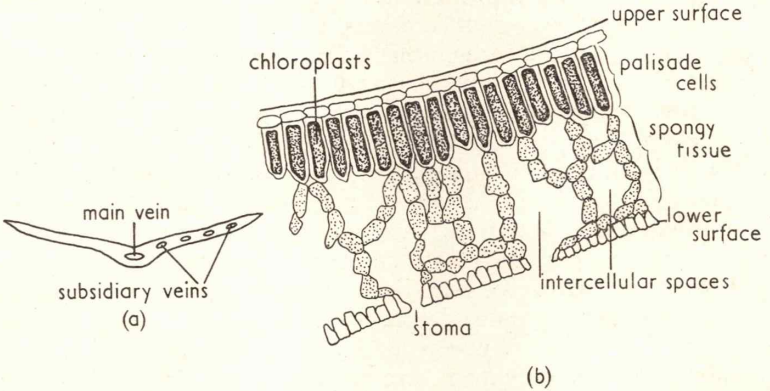

FIG. 5. Cross-section of a leaf: (a) Low magnification; (b) High magnification.

The stomata control the rate of exchange of gases and water vapour between the plant and the air. In your earlier work you found that the stomata are more numerous on the lower surface of the leaf. In most plants these stomata open by day and close by night.

In respiration, air enters through the stomata; oxygen is used, and the waste gases are given off through the stomata. In *photosynthesis*, air enters through the stomata, carbon dioxide is used, and the waste gases, plus the extra oxygen, are given off through the stomata. Water and mineral salts from the soil are transported by way of the xylem to the chloroplasts in the leaves, where, in combination with carbon dioxide from the air, and in the presence of sunlight, these raw materials are manufactured into sugars, etc.

The manufactured foods are generally transported from the leaves to be used or stored elsewhere in the plant. Thus the leaves are the industrial centre of the plant. Therefore, if a plant is stripped of its leaves by disease or insects it rapidly withers and dies. Nevertheless the stem and roots are just as necessary for healthy growth; e.g., if a tree is unnecessarily ring-barked by men and children, and by animals such as rabbits and deer, water and mineral salts will not reach the leaves. Careless cultivation, particularly with shallow-rooting plants, the lemon for example, may cause damage to the roots, and thus impede growth.

TYPES OF FRUITS

In your earlier work (*General Science*, pages 180-4) you studied the structure of the flower and the processes of pollination and fertilization which resulted in the formation of a fruit. Probably most of you think that the term *fruit* is used for only such things as apples, oranges, and bananas, but a fruit is that part of the plant which contains the seeds, and therefore includes widely different types such as apples, wheat grains, and dandelion seeds. Who would think of eating the fruit of a wallflower, poppy, or bidi-bidi? On the other hand we do eat lots of things which you probably do not consider as fruits, e.g. tomatoes, peas, beans. Make a list of fruits that are used as foods (e.g. pumpkin), or from which foods are manufactured (e.g. wheat). You should be able to get at least twenty.

There are many different ways of classifying these fruits, depending upon whether we study their form, their structure, or their function. The system we will use will divide them first into *succulent fruits* and *dry fruits*. The fruit is made up of the *seed*, which was the ovule, and the *pericarp* which was the wall of the ovary. The pericarp, and the top of the stem, which is called the *receptacle*, or just the pericarp, may produce the fleshy part of a fruit (*Fig. 6a*). If it does become fleshy the fruits are called succulent fruits; if it remains dry the fruits are called dry fruits. The pericarp may be further subdivided into *epicarp* or outside portion, *mesocarp* or middle portion, and *endocarp* or inner portion. One of these portions may become specialized. The epicarp in the orange is the rind, and the endocarp in the plum is the stone.

To Study Succulent Fruits

PRACTICAL WORK Cut a plum longitudinally, i.e. from top to bottom through the stem. Notice there is only one seed enclosed in the endocarp or stone. The fleshy part has been formed from part of the pericarp or wall of the ovary (*Fig. 6b*).

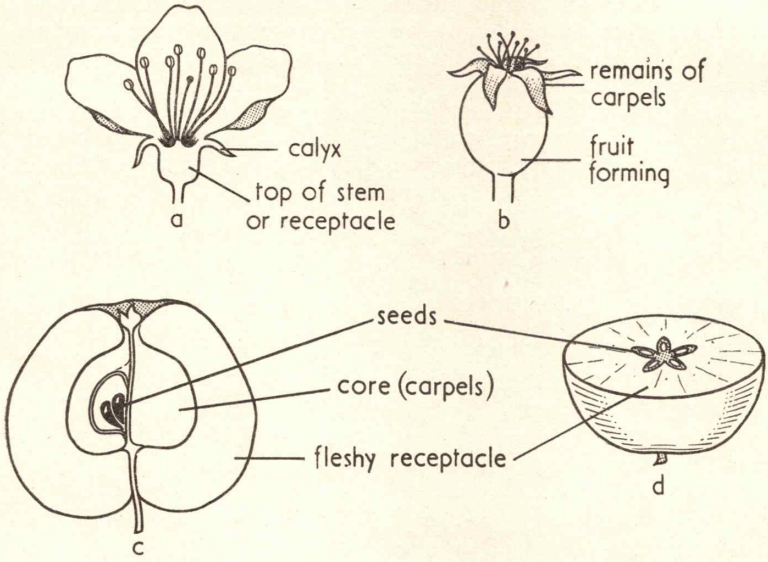

FIG. 6A. Flower and section of apple.

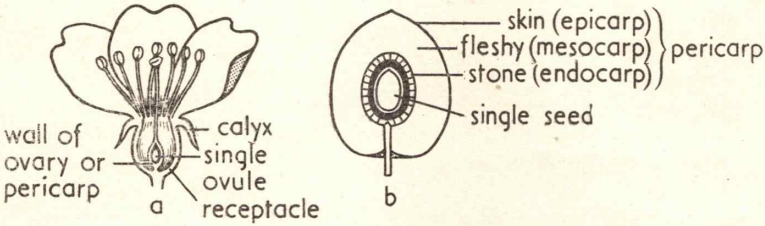

FIG. 6B. Flower and longitudinal section of plum.

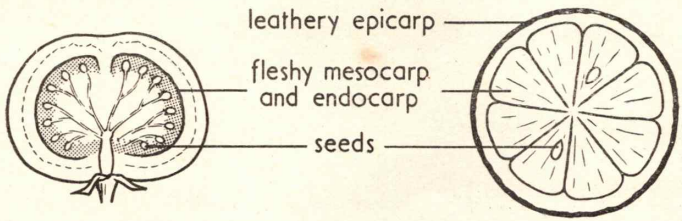

FIG. 6C. Longitudinal section of a tomato (left), and transverse section of an orange (right).

Cut one orange or tomato longitudinally and one transversely. Notice that the seeds are scattered in the fleshy portion and that there is no hard stone. In oranges and lemons the epicarp is leathery, but it is eaten in the form of candied peel (*Fig. 6c*).

Cut one apple in half longitudinally and another apple transversely. Notice that the fleshy part is the swollen top of the stem or receptacle, while the core is formed from *carpels* which contain the seeds (*Fig. 6a*).

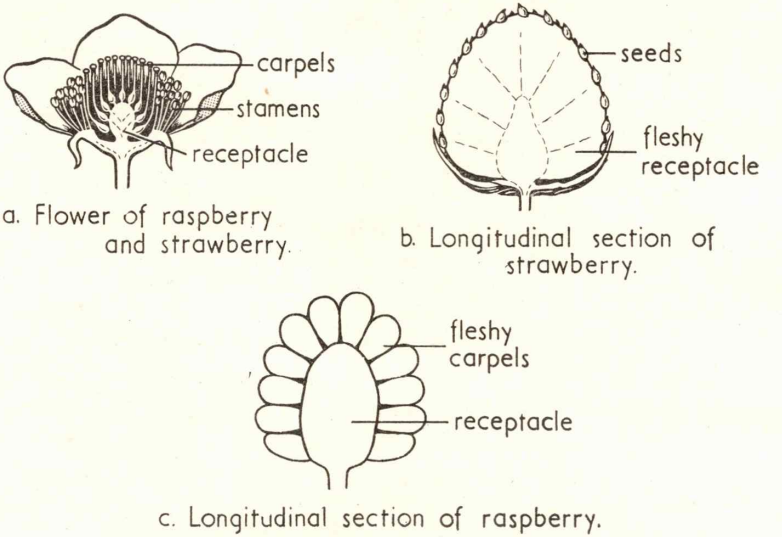

Fig. 7A. Longitudinal sections of flowers and fruits. (a) Flower of strawberry and raspberry; (b) fruit of strawberry; (c) fruit of raspberry.

Cut a strawberry and a raspberry longitudinally. Notice that although they are formed from a similar flower, the fleshy part of the fruit is in one case the receptacle, and the other a collection of *drupelets* (little drupes) covering a receptacle (*Fig. 7a*).

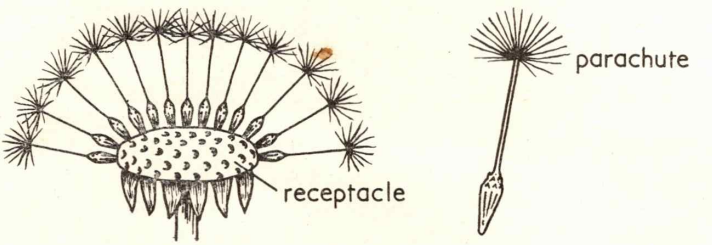

FIG. 7B. Dandelion fruit.

To Study Dry Fruits

PRACTICAL WORK Examine the seeds of a dandelion. Notice that the parachute is a collection of smaller parachutes, each one having at its base a single seed (*Fig. 7b*). See how many different plants you can collect which have this type of fruit. Collect the fruits of delphinium, gorse, broom, pea, wallflower, shepherd's purse, poppy, snapdragon, scarlet pimpernel. Leave them to dry out, and notice which way they split to set free the seeds (*Fig. 8*).

CLASSIFICATION OF FRUITS

A. Succulent Fruits: Pericarp usually differentiated into layers, one of which is succulent.

1. FROM ONE FLOWER

   (a) *Drupe* (one-seeded). Three layers, protective epicarp, succulent or fleshy mesocarp, hard or stone endocarp, e.g. cherry, plum, peach, coconut, and walnut. In the last two examples we buy only the endocarp and seed of the fruit. The other portions have been already removed before sale.

   (b) *Berry*. No hard endocarp, e.g. grape, gooseberry, orange, tomato, cucumber, banana. Some tomatoes and oranges have very few seeds.

   (c) *Pome*. Fleshy receptacle, e.g. apple, pear, and hawthorn.

   (d) *Aggregate Fruits*.
   i. Carpels succulent, e.g. raspberry, blackberry.
   ii. Receptacle succulent, e.g. strawberry.

2. FROM AN INFLORESCENCE

   Inflorescence variously fleshy, e.g. pineapple, mulberry, fig. In the case of the pineapple the fruit is made up of the whole inflorescence, the receptacle, and the flower stalks, all of which become succulent.

B. Dry Fruits

1. *Dehiscent*. Splits generally in a regular manner to free the seeds, e.g. marigold, delphinium, rewarewa, bean, pea, kowhai, wallflower, stock, turnip, shepherd's purse, honesty, carnation, snapdragon, poppy, scarlet pimpernel.

2. *Indehiscent*. Are generally one-seeded, and do not open, e.g. dock, sorrel, buttercup, daisy family, grasses, nuts, carrot, radish, sycamore.

These dry fruits may be further subdivided according to the structure and where they split open.

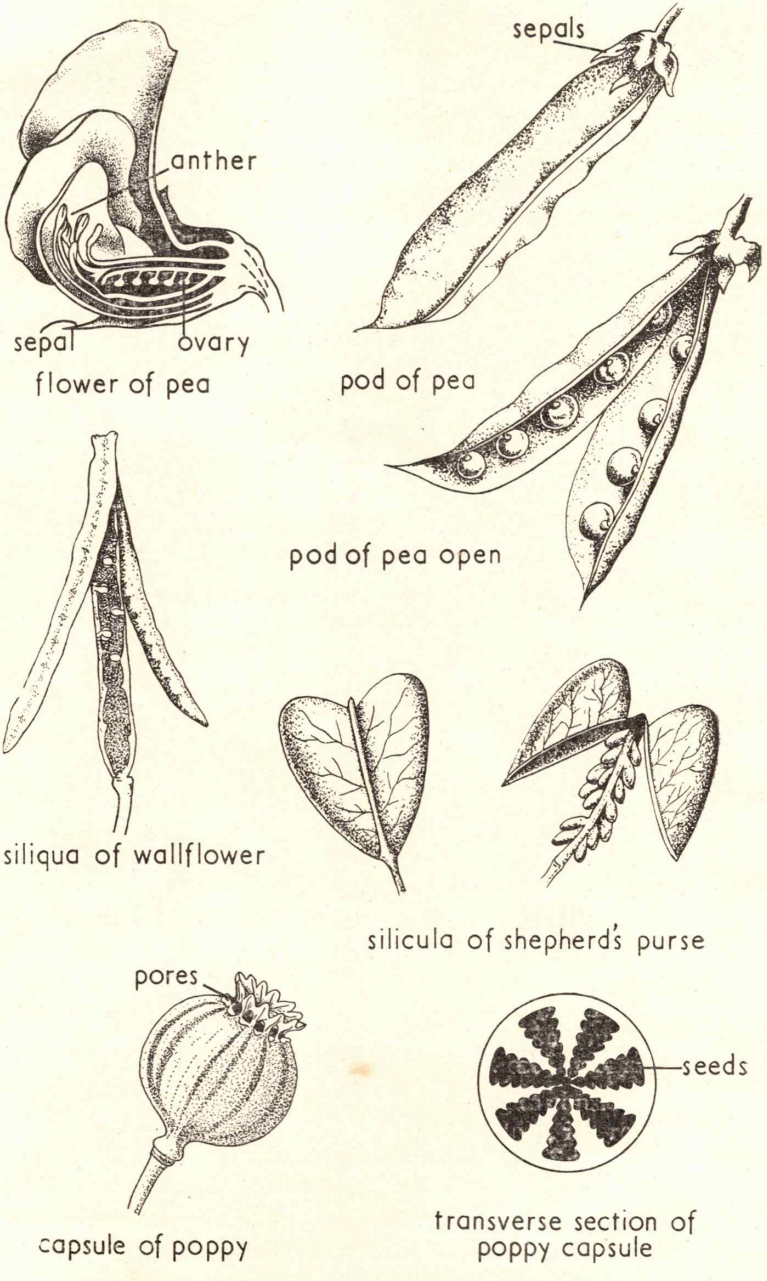

Fig. 8. Types of dehiscent fruits.

SUMMARY

Vascular bundles are composed of xylem, phloem and cambium.
Xylem transports water and mineral salts in solution.
Phloem transports manufactured foods in solution.
The greater proportion of a tree is dead xylem.
A fruit is that part of the plant which contains the seed or seeds.
Succulent fruits may be classified as drupe, berry, pome, or aggregate fruit.
Dry fruits may be classified as dehiscent or indehiscent.

2

Excretion

EVERY ENGINE in which chemical reactions take place produces waste products. If these are not removed the engine will stop. A steam engine has a funnel or chimney for the removal of waste gases, and solid ashes are removed from the fire box. A motor car has an exhaust pipe through which waste gases are led away.

All living plants and animals need energy. To obtain this energy they burn foods in the living cells. This slow burning of foods is called *respiration*, and in the process plants and animals produce waste products which also must be removed.

Plants do not move, and so require very little energy. Consequently they produce a relatively small quantity of waste products, and these are built into the walls of the cells. In animals more energy is needed, and so more waste products are produced. If they were allowed to accumulate, these waste products would very soon poison and kill the animal. The removal of waste products from the animals' bodies is called *excretion*, and all animals from *Amoeba* to man have special structures, cells, or organs for the removal of these waste products.

In your earlier work you learned how *Amoeba* flowed round a particle of food and after it had absorbed the useful portions, it excreted the remainder. From the air dissolved in the water it also took oxygen and returned carbon dioxide to the water.

Higher animals are much more complicated, and have more elaborate methods of eliminating waste matter.

In man, food is eaten and chewed in the mouth. It then passes down the alimentary canal and is digested in the stomach and small intestine. The useful portion of this food is absorbed in the small intestine. In the large intestine, much of the water is removed from this undigested food,* which may assume considerable proportions, particularly if the diet has been of a vegetable character, as it will therefore contain much cellulose. Added to this undigested food is the real excretion, which consists of waste products derived from the

*An excretion is a substance made in and later removed from the body. Strictly speaking, undigested food is not excreted as it has not been made in the body.

bile, and the cells of the intestinal wall. This *solid waste* matter is eliminated or voided through the *anus*.

The useful foodstuffs which are removed in the small intestine are circulated round the body to the different tissues. Oxidation takes place in the cells and carbon dioxide and water are collected by the blood and expelled into the lungs. This *gaseous matter*—carbon dioxide and water vapour—is excreted when we *breathe out*.

Other soluble waste products are collected from the tissues by the blood. These *soluble products* are then removed from the blood by *the kidneys* and *sweat glands*, and then excreted.

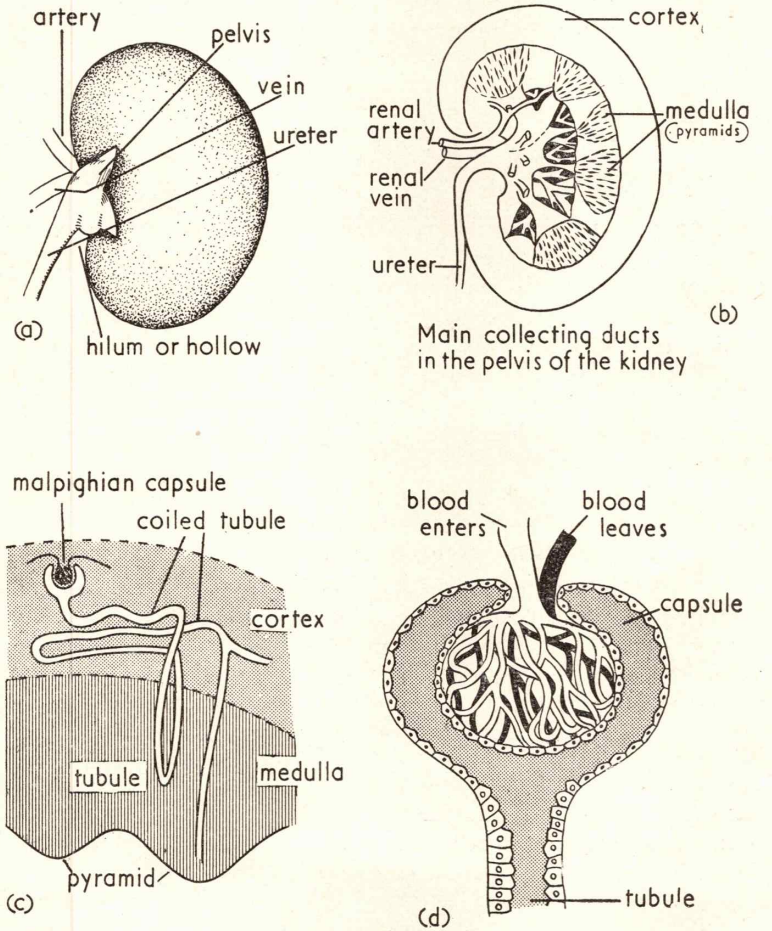

FIG. 9. A kidney. (a) External features; (b) Longitudinal section; (c) Uriniferous tubule; (d) Malpighian capsule.

THE KIDNEY

PRACTICAL WORK Cut a sheep's kidney longitudinally in half through the hollow or hilum and note that it consists of two distinct regions. The inner redder zone is called the *medulla*, and the outer browner zone is the *cortex*. The three tubes entering the hollow or *hilum* are the *renal artery*, *renal vein*, and the *ureter* (*Fig. 9*). Notice that the medulla is divided into twelve pyramid-shaped pieces of tissue, each of which leads into the pelvis and that the pelvis drains into the ureter. In your section you will probably see about six or seven pyramids. Examine a prepared slide of a cross-section of a kidney under the low and the high power of the microscope. Notice that the *malpighian* capsule*, which appears as a dot to the naked eye, is made up of a mass of capillaries surrounded by a capsule or bag (*Fig. 9d*). The capsule is connected to the pyramids by a coiled tubule (little tube).

The kidneys are particularly concerned with the removal of nitrogenous waste products. Blood containing urea enters the kidney by the renal artery, which subdivides into many branches, each of which enters the cortex and ends in a malpighian capsule.

Water, urea, uric acid, and various inorganic salts pass into the capsule. As this liquid passes along the tubules, certain useful substances, such as glucose, some inorganic salts, and ninety per cent of the water are reabsorbed into another set of capillaries which link up to form the renal vein.

The remaining liquid, which is called urine, is simply a solution of urea and other waste products. After it leaves the tubules it passes through the pyramids, pelvis, and ureter to the bladder, where it is stored and discharged at intervals.

THE SWEAT GLANDS

PRACTICAL WORK (1) Put some ether on the back of your hand. Notice that your hand becomes very cold.

(2) Examine the skin of the hand with a hand lens or the low power of the microscope and you will see that the surface is covered with very minute pores which are the openings of ducts from the sweat glands.

(3) Wear a rubber finger stall for approximately one hour, and collect some of the sweat in it. Use the flame test to test for the presence of sodium compounds.†

---

*Marcello Malpighi (1628-1694) was a great Italian microscopist who first saw many details of these structures.

†Dip a platinum wire loop into concentrated hydrochloric acid and heat in the bunsen flame. Repeat until the flame is no longer coloured. Dip the wire loop into the sweat and heat in the bunsen flame. If sodium is present the flame will be coloured a brilliant golden-yellow.

(4) Examine a prepared slide of a section of the skin under the low and the high power of the microscope. Observe that it consists of three layers: epidermis, dermis, and subcutaneous tissue. Notice the cut coils of the sweat glands, which will be seen mostly in the subcutaneous layer although some do occur in the dermis layer (*Fig. 10*).

The sweat glands, which are found in the *subcutaneous* and the *dermis* layers of the skin (*Fig. 10*), are richly supplied with blood vessels. Each gland consists of a highly-coiled tube which is connected to a pore on the surface of the skin by a coiled duct. The waste products removed from the blood pass to the surface of the skin, where warmth from the body and the movement of air evaporate off the water. The heat which is taken from the body cools the body, not as spectacularly as the ether, but it is the most important means of regulating body temperature (see *General Science*, page 334). Salt and other waste products are left on the skin and must therefore be washed off. On cold days the surface capillaries are much smaller, so that less fluid matter is excreted by way of the sweat glands but more through the kidneys.

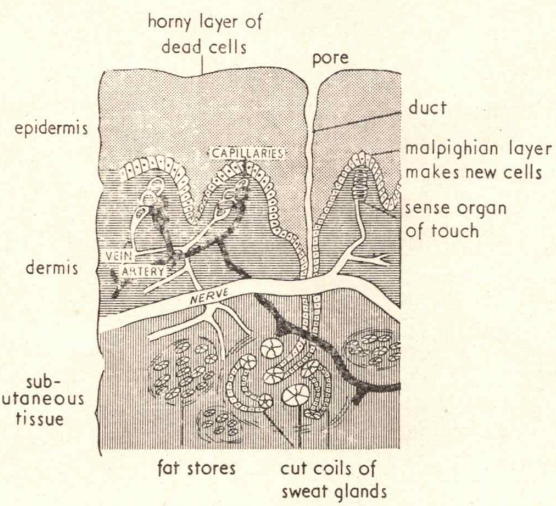

FIG. 10. A section of the skin, showing sweat gland.

THE LUNGS

PRACTICAL WORK (1) Repeat the experiment described on page 119 of the authors' *General Science*.

(2) Hold a polished mirror up in front of your mouth and nose and breathe on to it. The surface of the mirror becomes misty, and in cold weather drops of moisture may collect.

Waste gases and excess water from the blood pass into the lungs and are breathed out through the mouth and nose. Inspired air contains ·03 per cent carbon dioxide while expired air contains about three per cent. Expired air is also saturated with water vapour.

The lungs are similar to the sweat glands and the kidneys in that they are excretory organs, and at the same time each assists in the maintenance of body temperature.

SUMMARY

Solid waste matter is eliminated or voided by way of the anus.
Liquid waste matter is excreted by the kidneys and sweat glands.
The kidneys consist of two main regions, the outer cortex and the inner medulla. Malpighian corpuscles remove nitrogenous waste matter from the blood.
Sweat glands are found in the dermis and subcutaneous layers of the skin. These glands excrete water, salt, and a little urea.
Carbon dioxide and water vapour are excreted by the lungs.

3

Adaptation of Plants to their Environment

XEROPHYTES AND SUCCULENTS

YOU HAVE previously studied how plants breathe and feed. Water is absorbed from the soil and passes to the leaves by osmosis and transpiration. This water is essential to the plant, not only for its use directly as a food (carbon dioxide and water in the process of photosynthesis produce glucose), but also to carry the mineral salts and the manufactured food in solution. Excessive loss of water through transpiration can be very serious. The plant will wilt, photosynthesis will cease, and ultimately the plant will die. Temperature, shade, wind, nitrates and other mineral foods also determine the growth and type of plant which will adapt itself to a particular environment, but by far the most important factor in this respect is the presence of adequate water.

Plants which grow in an environment in which the water supply is adequate but not excessive are called *mesophytes* (Greek *mesos*, middle; *phyton*, a plant). The two extremes to mesophytes are *xerophytes* (Greek *xeros*, dry) which are modified in some way to withstand dry conditions, and *hydrophytes* (Greek *hydro*, water) which, like watercress, can live in water. Plants adapted to a particular environment form 'plant societies'* and such a society will be found where like conditions arise.

Mesophyte societies require a moderate rainfall. In New Zealand, examples of mesophyte societies are the subtropical rain forest, the subantarctic rain-forest or beech forest, and the grasslands. Grasslands require less but evenly-distributed rainfall, and beech forests tend to dominate as latitude and altitude increase. Consequent upon an increase in altitude, the situation generally becomes more exposed, and therefore there is less water in the soil; but the beech forest is not a xerophyte society, and will give way to other plant societies if the conditions become really dry. It is not proposed to enter into

*'Plant societies', 'plant communities', 'plant associations' are often used synonymously.

details of the structure and distribution of the forest, and of types within the forest societies, that may be found in our magnificent New Zealand forests but those who are interested should read Dr Cockayne's books.*

Xerophyte societies are plant societies found in dry situations such as sand dunes and wind-swept ridges. Plants which live in such an environment are modified to prevent excessive loss of water by transpiration. When your mother hangs the washing out to dry she wants, more than anything else, a fairly steady wind. Wind dries the clothes more quickly than the sun alone, as the rapid air stream, sweeping over the clothes, takes the moisture out of them. In the same way, wind sweeping over the surface of a leaf will tend to evaporate the moisture from the leaf more rapidly and therefore increase the rate of transpiration. If there is a plentiful supply of water, or the wind is not excessive, the plants do not have to modify their structure. But if the plant is growing in a dry situation this excessive transpiration, if maintained, will kill the plant.

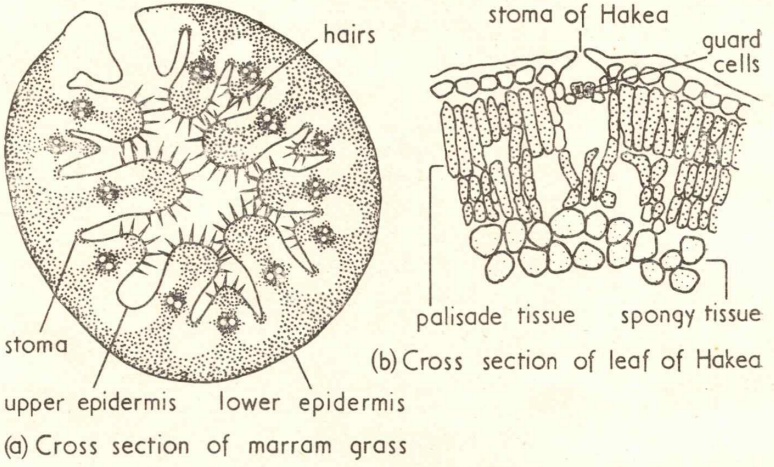

FIG. 11. Cross-sections of xerophyte leaves:
(a) Marram grass; (b) Hakea.

TO STUDY XEROPHYTE PLANTS

PRACTICAL WORK Examine the stem of New Zealand broom (*Carmichaelia*). Notice that it is flattened, ridged, and green, and that there are no leaves. This type of stem in which photosynthesis takes place is called a cladode.

**The Trees of New Zealand*, L. Cockayne and E. P. Turner, should be in every school library.

Examine a Wild Irishman (*Discaria*) plant and notice that although leaves may be present in the spring they have been completely replaced by autumn by large green spines.

Examine with a hand lens the leaves of Akepiro (*Olearia furfuracea*). On the back you will see a very dense layer of hairs.

Examine a twig of manuka (*Leptospermum*). Notice the very reduced leaf surface and the hard, very brittle leaves.

Cut sections of leaves of bracken (*Pteridium*), marram grass (*Ammophila*), and Australian needle bush (*Hakea acicularis*). The leaves of bracken are curved, hard and leathery and in cross-section there is a lack of stomata on the upper surface and there are epidermal hairs on the lower surface. Marram grass has a rolled leaf and the stomata are confined to the bottom of the grooves which are inside the roll and on this inside roll will also be found hairs (*Fig. 11*). *Hakea* has greatly depressed or sunken stomata and the tissue of the leaf contains numerous water storage cells (*Fig. 11*).

All of the above plants have become adapted to their environment by modification. Water is lost by transpiration through the stomata in the leaves. Hence, any modification is seen in the leaves and in the protection of the stomata. The first way in which xerophytic plants are modified is to reduce the area of leaves to a minimum. New Zealand broom, manuka, gorse, and Wild Irishman are examples of this. Broom has reduced the leaf surface to such an extent that there is not sufficient for photosynthesis. To overcome this the stem or *cladode* contains the chloroplasts and is green. The water loss from a cladode is much less compared with the loss from a leaf surface; but a cladode is almost as efficient as a leaf surface as a photosynthetic region. Broom is frequently found growing in regions which are other than dry; but for a plant to have reduced its leaf surface to *nil* would indicate, with other considerations,* that New Zealand formerly had a climate much drier than it is now. Similar leaf reduction is found in the rimu, tanekaka, and toa-toa. With Wild Irishman the leaves are fairly abundant in spring but by autumn they have entirely disappeared, their place being taken by large green spines. Dr Cockayne carried out an experiment with Wild Irishman which earned him world-wide fame on the subject of xerophytes. He grew a plant from the seedling stage, maintaining it in a warm moist atmosphere, and found that the green spines were not developed but that the seedling leaves were retained. Thus it can be seen that Wild Irishman readily adapts itself to the dry conditions in the sand dunes and ridges that form its habitat.

Plants can reduce the amount of water lost by transpiration:

(a) By having stomata only on the lower surface, e.g. bracken and Australian needle bush.

*Geological.

(b) By rolling under the edges of the leaf, e.g. bracken and tauhinu.
(c) This rolling may be carried to such an extent that the leaf is no longer recognizable as such but becomes a needle, e.g. pine. The members of the *Pinus* family, which are not native trees of New Zealand, normally grow in regions covered with snow, which at certain periods of the year freezes over so that water is not readily available to the plant. In marram grass the whole leaf rolls up, forming a tube within which a relatively moist atmosphere can be maintained. Thus with the rolled leaf, with stomata only on the bottom of the grooves, and further protected with stiff hairs, marram grass is well fitted to withstand dry conditions, and has proved the most valuable sand-binder in New Zealand.
(d) By covering the back of the leaves with a dense layer of hairs which act as a breakwind and thus prevent evaporation, e.g. Akepiro.
(e) By having sunken stomata which are away from the direct draught of the wind, e.g. Australian needle bush. This plant is an Australian xerophyte which is so modified to withstand dry conditions that it has even ousted some New Zealand xerophytes in areas where it has been introduced.

One other method of overcoming dry conditions is for the plant to store water in its tissues. Such plants are called succulents. This modification is well shown in cacti and in some 'ice' plants. In cactus plants the leaves have become very sharp spines, which not only reduce the rate of transpiration, but also protect the plant against animals which would be only too keen to eat the fleshy stems that are a storehouse of water and food to tide the plant over the periods of drought so frequent in deserts.

Perhaps you may study a xerophyte society in your field study, in which case you will find manuka, bracken, etc., growing in the one environment. However, a word of caution: not all plants found there grow only in dry situations. Frequently gorse will take over when bush or pasture has been burnt. However, later the gorse will possibly be replaced by manuka, and finally by species of subtropical forest of the mesophyte society. The gorse invades the newly-burnt land because of its vigorous growth, not because it is a xerophyte.

Hydrophyte societies are plant societies which live in water. These plants have a thin epidermis through which the minerals and gases dissolved in the water are absorbed. Consequently there is no need to have a root system for absorption of food, so that the roots are largely for anchorage. The plants which live in water do not require special strengthening tissues (xylem) to hold them upright, as the water supplies all the support that is needed. Examples of hydrophyte plants are water-cress, Canadian pond weed (Elodea), water-milfoils (*Myriophyllum*), water hyacinth, and water lily.

4

Adaptation of Animals to their Particular Mode of Life

EARTHWORMS, insects, fishes, frogs, and birds have all been mentioned in the work you have previously done in General Science. We will study each of them further with reference to its adaptation to its particular mode of life.

THE EARTHWORM

PRACTICAL WORK Collect some earthworms. This can be done by digging in the garden, but a quicker and more convenient method is to pour a 10 per cent solution of formalin* over a patch of lawn where there are worm casts. The formalin will force the earthworms to the surface. Other home disinfectants may be used, but they do not give such good results as formalin. If the earthworm is not completely out of the hole, seize it when its body emerges and pull it completely out with a steady pull. If you are using formalin, wash the earthworms in water or they will probably be killed. If the earthworms are wanted for dissection, lay them out in a tray of water and kill them by slowly adding alcohol. If the alcohol is added too quickly, or if formalin is used the earthworms twist and tie themselves up in knots. Preserve and fix the earthworms in 5 per cent formalin.

Notice that the earthworm is made up of segments. The head is the pointed end and the tail is the flattened end. There are about 150 segments from head to tail, and in a mature earthworm a belt or saddle occurs from the thirty-second to the thirty-seventh segments. Run your finger along the underside or ventral surface of the earthworm and feel the bristles on each segment. These bristles or *setae*‡ assist in movement. Place a live earthworm on a sheet of newspaper. Listen to the scraping noise as it moves across the paper. Notice how it elongates the front portion first and then pulls up the hind portion. Now place the worm on a slightly moist piece of glass. The worm slips and slides in all directions because it cannot get a grip with the setae.

Pin a preserved earthworm under water to the dissecting tray with the dorsal† surface uppermost and carefully cut down the mid line, pinning

*Commercial formalin is 40 per cent.

†The dorsal surface can be easily distinguished from the ventral surface by running your finger along each surface. The dorsal surface has no setae or bristles.

‡Sometimes called *chaetae*.

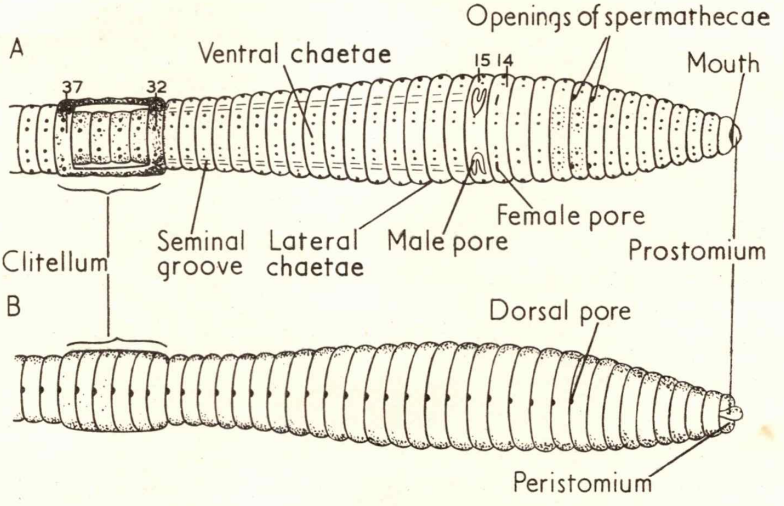

FIG. 12. The anterior or front end of the earthworm: (a) Ventral or under view; (b) Dorsal or top view.

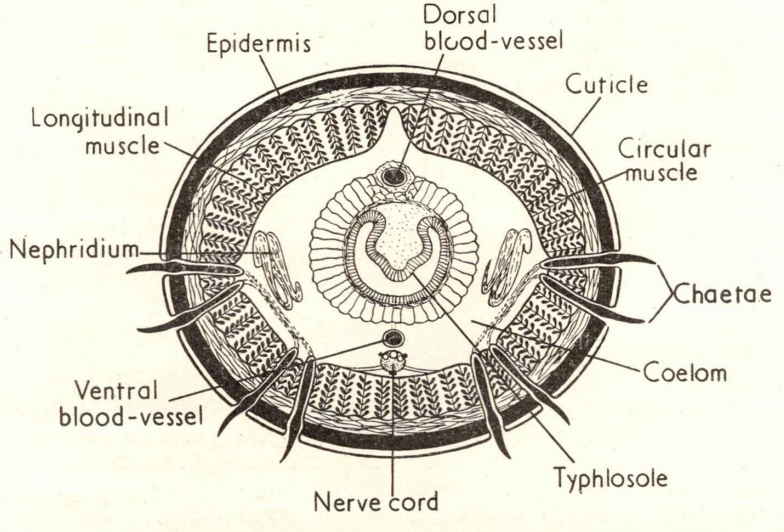

FIG. 13. Transverse section of the body of an earthworm.

back the flaps as you proceed. The internal organs of digestion and reproduction will be exposed (*Fig. 14*). The digestive organs are fairly easy to distinguish. The pharynx has many white threads holding it to the body wall. The white threads are muscles which enable the pharynx to grip leaves, etc. The oesophagus is a narrow tube which opens out into a soft bag-like crop which stores the food until it is broken up and digested in the hard and muscular gizzard. The intestine is a straight tube which runs from the gizzard to the anus, where solid waste matter is eliminated.

The reproductive organs are much more difficult to see. In the large white structures which overlap the oesophagus, sperms develop and mature. If you look very carefully beneath these, you may see four very small white balls smaller than a pin-head. These are the testes, where the sperms begin to form. Behind the testes are two white pear-shaped ovaries about one-tenth of an inch in diameter.

Carefully remove the digestive organs, and you will see on the under surface the ventral nerve, which has three short side branches in each segment.

The earthworm is a segmented worm. The segments are indicated externally by ring-like constrictions. It is a nocturnal animal and lives in a burrow under the ground. The earthworm comes to the surface at night when it is safe from attack by its natural enemies, the birds. If you go out at night and study a piece of lawn you will see earthworms half out of their burrows. They may have the head portion out, in which case they will be feeding within the radius of their burrow; or they may have the hind portion out, in which case they will be getting rid of waste matter that they deposit in the form of worm casts. Earthworms must be stalked with some care, because they are extremely sensitive to vibrations of the earth caused by a heavy-footed observer, and will immediately retract into their burrows. If you try to pull an earthworm out of its burrow and are not very quick, it will grip the sides of the burrow most tenaciously with the setae. If you continue to pull, the earthworm is more likely to break in two than to relax its grip.

The earthworm feeds on soil and organic matter, e.g. dead leaves, which it stores in the crop and pounds up in the muscular gizzard. The food passes on down the intestine where the valuable part is absorbed by the blood vessels in the walls of the intestine, and the waste matter is eliminated through the anus.

The earthworm moves with its ventral surface in contact with the ground and as this is where impulses and vibrations will normally come from, the nerve cord runs along the ventral surface. There are four pairs of setae in each segment, and it is by means of these, in conjunction with circular and longitudinal muscles of the body wall, that the earthworm is able to move. The setae can be retracted like the retractable undercarriage in a modern aeroplane. The posterior

(rear) setae grip the soil and the anterior (front) setae are retracted. The circular muscles which run round the body wall of the earthworm are contracted so that the earthworm becomes longer and thinner. The back portion of the earthworm is fixed so that the front portion moves out. Then the reverse process is carried out. The anterior setae grip the soil, the posterior setae are retracted, the longitudinal muscles of the body wall which run up and down the earthworm are contracted. The earthworm becomes shorter and fatter. As the front portion of the earthworm is fixed the hind portion moves up.

The earthworm has become adapted to life on land and breathes through its moistened skin. However, as earthworms are the food of many birds, they have had to assume a nocturnal habit to avoid being eaten, and the only time we see earthworms is when we dig them up in the garden, observe them at night, or when rainwater washes them out of their burrows.

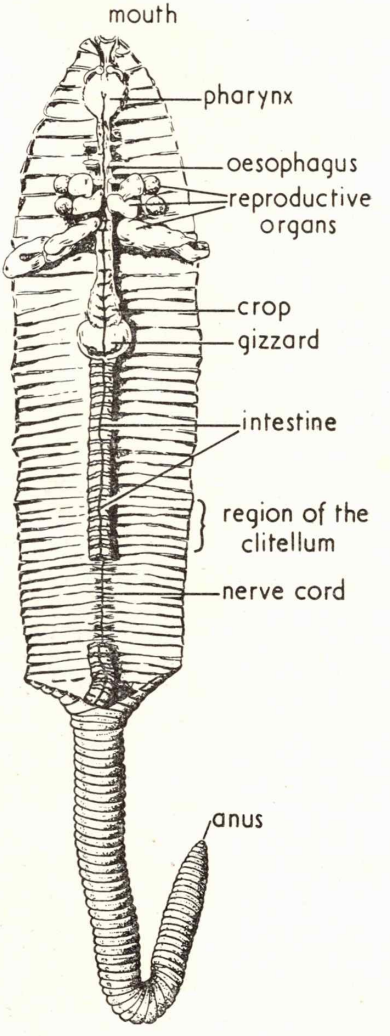

FIG. 14. Dissection of the earthworm.

INSECTS

Insects belong to the phylum *arthropoda* which is the largest phylum in the animal kingdom. In this phylum, insects are only one class, but this class includes over half a million different species, approximating seventy-five per cent of all animals. Naturally, for a class of animals to be so widespread as to be found in almost all possible situations, that class must show a great diversity in its adaptation

to the varied modes of life in which it will be found. We will concern ourselves with only a few of the species commonly found in New Zealand. No doubt you will discover many other examples of insect adaptation in your field study.

Habitat

Insects may live on the land, in the air, or in water. Their habitat will to some extent govern their method of feeding, respiration, movement, and reproduction. This does not mean that all insects that live in the water will show the same adaptation, viz. some of them swim, some crawl in the mud at the bottom, and some are jet propelled by expelling water. It does mean that the insects will show adaptations which enable them to live in that particular habitat.

Feeding

You already know that the insect life history is divided into two, three, or four stages. Complete *metamorphosis* includes four stages, viz. egg, larva, pupa, and adult or imago as is found in the white butterfly. In incomplete metamorphosis there is no *pupa* or resting stage, but the young insect or nymph develops from the egg and passes through several moults and changes in structure before becoming adult, e.g. earwigs, dragon-flies. In a few cases the young insect on hatching resembles the adult in all respects and attains the adult stage by simple growth, e.g. silverfish. Whether there is complete or incomplete metamorphosis in the life history of the insect, the female makes provision for the young. Food is the prime need of the developing *larva* or *nymph*, and great care is taken to ensure that this is adequate. The white butterfly lays its eggs on the back of cabbage leaves. The honey bee builds a comb and lays an egg in each cell. The larvae are fed on 'royal jelly', pollen, or honey by the workers. The borer beetle lays its eggs in soft sappy timber; *Pteromalus puparum* lays its egg in the pupa of the white butterfly. The mason-wasp lays its eggs on the bodies of paralysed spiders which it then seals up in clay. Codlin moths lay eggs in the blossoms which later form apples. Thus in each case an abundant storehouse of food for the larvae is provided.

Mouth parts are modified to suit the type of food that will be eaten. The larva of the white butterfly has horny jaws with which it eats the leaf of the cabbage, but the adult insect has a coiled proboscis as it feeds on nectar (*Fig. 15*). Moths and butterflies feed in this way. Flies also suck up their food in a liquid form, but their feeding habits are unpleasant and dangerous to man. The proboscis is a short tube which widens out at the end. The tube is pushed down on to the food on which the fly is feeding and a liquid is poured over

the food, which is dissolved and then sucked up. Flies may have come straight to your sugar basin from the manure heap, and therefore may carry disease which will affect your health.

The weta, which feeds on solid food, has well developed mouth-parts for biting or tearing and mincing its food. In this insect the mouth-parts or jaws are varied and complex (*Fig. 15*); The *labrum* holds the food while the *mandibles* bite across it; the *maxillae* are sensory. The labrum and *labium* form the lips of the mouth cavity, holding the food for the mandible to chew, and at the same time pushing the food into the mouth. Beetles and wasps also eat in this way.

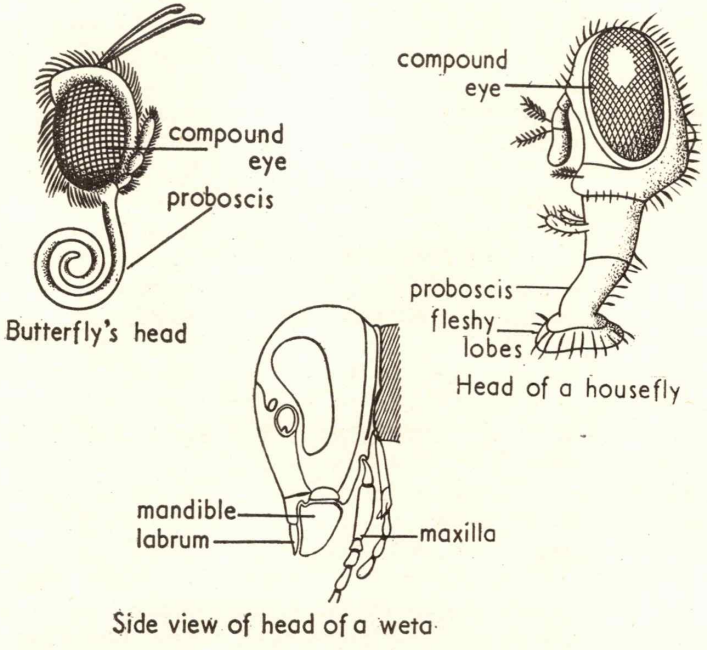

FIG. 15. Heads of insects: (a) Butterfly's head; (b) Head of a housefly; (c) Side view of head of a weta.

Other insects feed on liquid food but have first to pierce the external cells of the plant or animal to enable them to suck the sap or blood of the host. In such insects a coiled proboscis would be useless. Insects such as aphids, mosquitoes, and gnats have a labium that is modified to form a rostrum or 'beak' which is able to pierce the surface so that they can suck up their food. In the case of the

mosquito the mandible and maxillae bite or make the actual wound, and the insect's saliva enters the blood, thus spreading diseases among man and other animals.

The spider spins a web to catch flies. The caddis fly larva, which lives in streams, builds a net to catch its food. The praying mantis has unusually long forelegs for seizing its prey. The honey bee has special baskets or *corbiculae* on the hind legs in which the pollen is carried. The process of collection and storing of pollen is most intricate and interesting, but is most essential, as pollen is almost the sole source of minerals, proteins, and vitamins for these insects.

Respiration

Most insects absorb oxygen from the air through *spiracles*. This air is then carried to all parts of the body by an intricate system of delicate tubes called *tracheae* (see *General Science*, page 335). But those insects, or insect larvae and nymphs, which live in water show varied adaptation to their environment. Some have abdominal gills, e.g. may-fly nymphs, stone-fly nymphs, and caddis-fly larvae; some have breathing tubes or siphons which reach to the surface, e.g. hover-fly larvae and mosquito larvae; some rise to the surface and trap bubbles of air under the wings or in the hairs of the body, e.g. water boatman and whirligig beetle. If you study a fresh-water pond or stream as your field study you will find many such examples of adaptation.

Camouflage

The pupa is a resting stage, but the larva does not generally pupate on the plant or animal which provided its food. The white butterfly grub, for example, chooses some less conspicuous place and pupates on fence posts, thistle bushes, etc., and generally it tones in with the colour of the surroundings.

The colouring of the adult insects can show considerable variation. Stick-insects may be green or grey-brown, and are very difficult to see unless removed from their natural background colours. There are many examples of tropical insects whose colouring closely resembles that of the twigs, leaves and flowers that form their natural environment. If the colour is combined with a modification of form, such as is found in the stick insect or in butterflies and moths, to resemble sticks and twigs, then the insect has truly undergone adaptation to protect itself. (See *Plate 2.*)

Movement

Adult insects vary in their mode of locomotion, depending upon whether they live in the air, on the land, or in the water. Obviously

for those which go from flower to flower feeding on nectar and pollen, the easiest means is by flying, e.g. moths and butterflies. Those which live on land have much stouter legs for walking or running and some have well-developed hind legs for jumping, e.g. grasshoppers, locusts, and fleas. Some which live in water have their legs modified so that they resemble oars, e.g. water boatmen. Irrespective of where they live, they are all adapted to their particular mode of life.

Reproduction

Insects are the food of many carnivorous animals, e.g. insects, birds, and fish. Furthermore, man is continually waging war against some species of insects, e.g. mosquito, white butterfly, locust, aphids by chemical and biological means (see *General Science*, pp. 196 and 378). The high mortality can only be overcome by the production of a large number of eggs. The female may lay as many as several million eggs, e.g. termite. Fortunately not all insects reproduce in such prodigious numbers, viz. the white butterfly may lay up to 400 eggs, the blowfly 3000 eggs, and the queen honey bee 1500 to 2000 eggs a day, at the peak of the season. The eggs may be of two types:

(a) *Fertilized.* In insects the sexes are separate, and sperms are injected into the female and stored until they unite with the ova to produce fertilized eggs. The majority of insects produce fertilized eggs.

(b) *Unfertilized.* In some insects, e.g. aphids, saw-flies, and honey bee, the female lays unfertilized ova which develop into adult insects. This method of reproduction is called *parthenogenesis* and may be considered a degenerate form of sexual reproduction. In some species of insects only males develop from these unfertilized ova and females from the fertilized ova, e.g. honey bee. In other species, male or female insects can be produced from these unfertilized ova, e.g. in aphids during summer, females develop from these unfertilized ova; but in autumn some of the aphids produced are males. Parthenogenesis has the advantage of producing many offspring without fertilization. But parthenogenesis would in time produce a weakening of the species if this was the only method of reproduction (see *General Science*, page 343).

Community Life

Not only have insects adapted their way of feeding, respiration, movement, camouflage, and reproduction to their mode of life, but

there are even special duties assigned to various insects when they live as a community, e.g. ants, bees, wasps, and termites. In fact a bee, if separated from its community, soon dies. Within this community there are queen bees and workers (females) which develop from fertilized ova, and drones (males) which develop from unfertilized ova. The workers may work in the hive, go out to collect pollen or nectar—usually not both—guard the hive, or ventilate the hive with their wings to reduce humidity. The worker bees usually shift from one job to the next as they grow older. But they will do any job regardless of age as the needs of the community require.

Thus we can see that insects, which are the most numerous of all animals, and which are found from hot deserts to distant polar regions, live on land, in water, under the ground, indeed almost everywhere that life exists, and show a great variety of adaptations. In fact there is in the insects a variety of adaptations which far surpasses that of any other phylum of animals.

FISH

Fish are well adapted to their particular mode of life and have attained mastery over the water in which they live; but they do not show the intricacies and variations that insects do.

PRACTICAL WORK Obtain a fish from the local fisherman or fishmonger. Notice the shape, colour, and parts of the body. Identify the fins (*Fig. 16*). Open the mouth and notice the course taken by the water current. The gill slits may be obvious in some fishes, but in others the gill covers have to be lifted up so that the number and appearance of the gill slits can be observed.

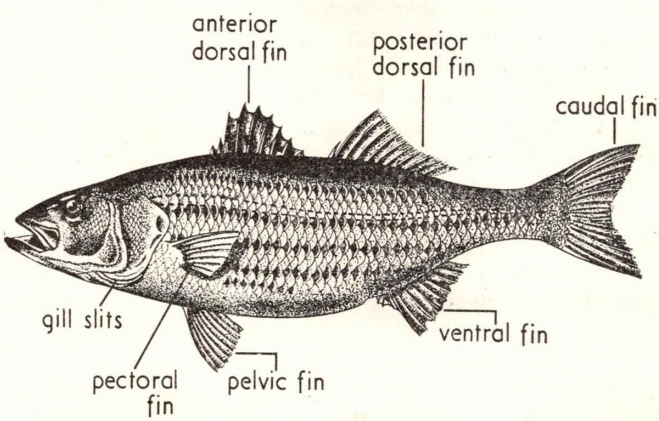

FIG. 16. The external appearance of a fish.

Fish live in water, in which they move and from which they obtain their food and air. They are streamlined, so that they offer less resistance to the water. Within this torpedo-like form occur variations for a particular mode of life. For example, flounders which live in the mud are flattened and both eyes are found on one side. Fishes such as cockabullies are flattened on the underside, and this adaptation allows them to swim closer to the bed of the pond, river or sea in order to feed. Fresh and salt water eels adopt a form which enables them to creep in and out of crevices of rocks and holes in the bank.

A large muscular tail would be a hindrance on land. In water powerful muscular contractions may propel a fish at speeds of nearly twenty miles an hour. The pectoral and pelvic fins act like flaps in an aeroplane, and assist the fish in ascending and descending and in steering. All fins contribute to maintaining balance, so that the fish floats evenly.

Fish obtain the oxygen they need from the air dissolved in the water. Water enters the mouth and pharynx. The mouth is closed and then the pharynx contracted, forcing the water out through the gill slits. As the water passes over the delicate filaments of the gills, dissolved oxygen passes into the thin-walled capillaries and carbon dioxide passes out into the water. The blood, which contains oxyhaemoglobin, is carried all over the body, and the oxygen is given up to those cells that require it.

The eel returns to the sea to breed, and this may involve travelling overland to reach a large river. The gill chambers are further modified to retain water for a considerable period to facilitate this overland journey.

The water which supplies the oxygen generally supplies the food. Minute plants and animals are filtered out of the water before it passes over the gill arches. Those fish which feed on diatoms, seaweeds, etc. generally have small mouths, while those that feed on and kill other sea creatures have powerful jaws and well-developed sharp teeth. The teeth, which are not used for chewing the food, but simply for biting it off or holding it, are continually replaced from behind.

Fishes are commonly a silvery colour, which is due to small particles of guanin in the skin. The brighter colours are partly due to pigment granules in the skin and partly to the structure of the scales. Many fishes can adapt their colouration to their surroundings. This adaptation is due to a change of pigment granules in cells of the skin. The colour change may be quite rapid, and in most cases is protective. Eels change their colour in migrating to sea, so that the back assumes a dark-green colour more in keeping with ocean waters. Flounders

fit perfectly into their surroundings, so that from above they mingle exactly with their surroundings; yet underneath they still retain the silvery colour.

THE FROG

The adult frog is an amphibian; that is, it lives on land and in water, and shows adaptations to suit its mode of life in both habitats.

The adult frog develops from a tadpole which lives solely in water and is therefore similar to a fish. The tadpole has a large muscular tail, a relatively small mouth for a vegetarian diet, and gills to breathe with. The adult frog loses this large tail, but develops hind legs which are muscular and much bigger than the forelegs. These web-bed hind legs are used in swimming, give the frog tremendous spring, and enable it to jump ten times its own length. The adult frog breathes by lungs, as most of its life is spent on land; but while it is under the water it can breathe through its skin. However, this method of obtaining oxygen is not completely successful, so that the frog comes to the surface of the water occasionally to obtain air. The nostrils and eyes of the frog are on the top of its head, so that most of its body remains below the water when it comes to the surface to breathe.

The adult frog feeds on insects, and to hold the insect in the mouth the eyes may be depressed so that they protrude into the mouth cavity, thus gripping the prey. The common frog of New Zealand is the imported *Hyla aurea*, which lives in ponds and streams and their neighbouring banks. The yellow green colour mingles with that of its surroundings. However, if you have an aquarium you will notice that if the frogs are kept in shady conditions, or are hiding under rocks, they lose these brighter colours and turn almost black. New Zealand native frogs, which do not live in such surroundings, are an inconspicuous brown that suits their natural habitat, the bush.

BIRDS

Birds have attained mastery over their particular environment, the air, just as fishes have over water. Many adaptations are shown in birds to enable them to accomplish their particular mode of motion, which is flight.

Great force is needed to raise a bird from the ground and to keep it in the air. The fusion of the vertebrae and the well-developed keel of the sternum provide firm anchorage for the strong well-developed muscles which raise and lower the wings (*Fig. 17*). The rate of wing-beat in house sparrows is 780 per minute, in ducks 540,

and in pigeons 480. The well-developed keel is absent in running birds, such as the ostrich and the New Zealand ground parrot or kakapo. The bones of the body themselves are at the same time very strong and very light—features which are also essential in the materials of the aeroplane. The streamlined shape of the body is conducive to rapid flight. The high position of the lungs and air sacs, and the low position of heavy organs such as digestive organs, keel, and muscles (*Fig. 17*) give the bird a low centre of gravity, and enable it to keep an even balance. The well-developed air sacs, which may have a greater capacity than the lungs, not only ensure a more perfect aeration of the lungs, but they reduce the relative density. These air sacs may even continue into the long bones and under the skin.

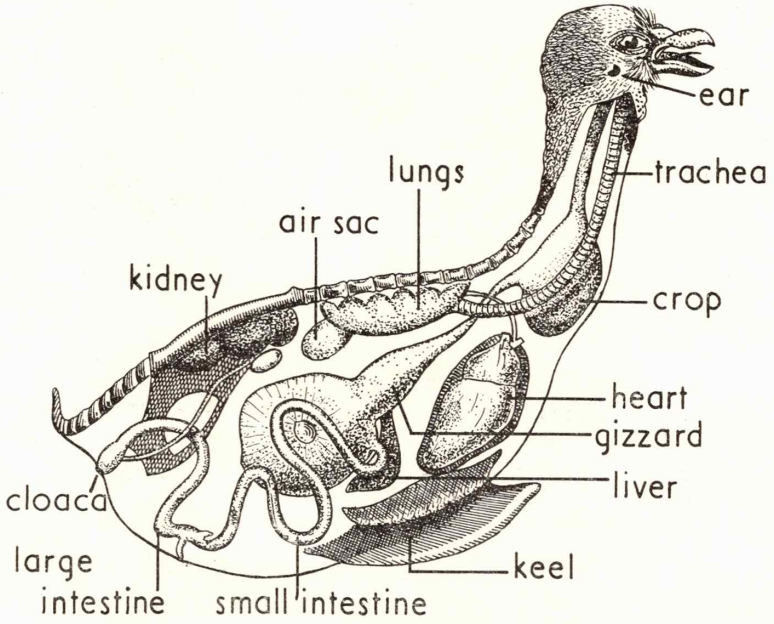

FIG. 17. The position of organs in a bird (diagrammatic).

The feathers of the wing and tail are used in flying and in steering. Each feather comprises a central quill, on each side of which is a flattened portion, the vane. The feathers offer great resistance to air in the downward stroke of the wing, but are less rigid and less air-tight on the upward stroke. The feathers of the wing, which are used in flight together with those of the body, retain a layer of air that is a bad conductor of heat and protects the body of the bird from cold.

The feathers also contain pigment granules which often give birds a most vivid hue. Coloured plumage is more common in the male bird, which shows it off to the full extent during courtship. In some birds the colouring closely resembles the normal background of their environment and thus serves as camouflage, e.g. bellbird, skylark.

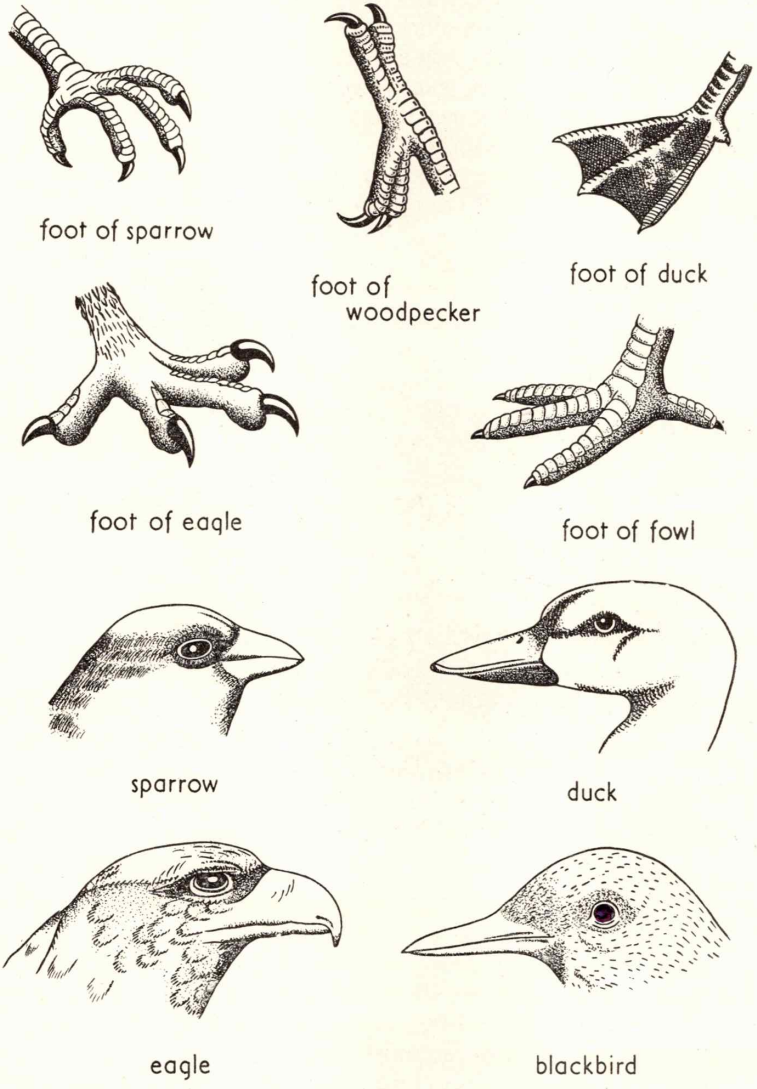

FIG. 18. Differences in the feet and beaks of birds.

The feet of birds show further adaptation to their particular mode of life (*Fig. 18*). They may have long claws for perching, like the sparrow. The domestic fowl's and pheasant's foot is similar to the sparrow's foot, but is much stronger, as these birds walk and scratch. The woodpecker and cuckoo have four claws, two pointing forward and two back. This arrangement is better for climbing trees. The duck and other birds which swim have webbed feet. The eagle, owl, and hawk have strong curved talons which are used to grip their prey and hold it while the bird tears it to pieces.

The beaks show adaptation to the type of food the bird eats (*Fig. 18*). The sparrow has a short blunt beak for cracking grain and seeds. The blackbird and thrush have pointed beaks which enable them to dig for worms. The very powerful hooked beak of the eagle permits it to tear its food apart. The duck has a broad flat bill or beak which it uses to shovel and strain the mud from which it obtains its food. The parrot's beak is much like a pair of nutcrackers—in fact this is what it is, as these birds feed on nuts. We see even greater adaptation in the now extinct New Zealand huia. The male huia had a sharp straight bill for chiselling away the bark of the tree, and after he had done his work the female picked out the insects with her long curved beak. Many of our smaller New Zealand birds, such as the silver-eye, fantail, rifleman, grey warbler, tom-tit, and robin have slender pointed beaks for picking up grubs and catching insects.

SUMMARY

Animals show adaptation to their particular mode of life.

Earthworms have segmented bodies, move by setae, live underground, and are nocturnal.

Insects show great variation in method of feeding, respiration, movement, shape, and colour. During development there may be either partial or complete metamorphosis. Most insects develop from fertilized ova, while a few develop from unfertilized ova, i.e. by parthenogenesis.

Fish live in water, have a streamlined body, move by fins, and adapt their shape and colour to their mode of life.

The frog is amphibian and lives in water and on land. The adult frog moves by jumping on land and swimming in the water. It breathes by lungs or through the skin, and feeds on insects.

Birds have streamlined bodies; most birds fly in the air, and the feet and beaks show special modifications to suit their varied ways of life.

5

Field Studies

DURING the Napier earthquake, the level of the sea bed was raised to such an extent that most of the inner harbour became dry land. Now most of the area has been converted into valuable farms.

If a similar occurrence took place off the coast so that an isolated island was formed, it would be interesting to watch the changes that would occur. In the beginning, there would be practically no living organisms at all, as those that were adapted to living in the sea would die off when the land dried out.

Although the birds, wind, and sea currents would bring a wide variety of seeds, only the salt-marsh type of plants would be able to establish themselves, as the soil would contain a considerable amount of salt. However, the rain would gradually wash this away so that in time the more usual type of vegetation would become established.

You have learned that all animals must obtain their food either directly or indirectly from plants. Those animals that could reach the island (birds, amphibians, insects, etc.) would tend to settle there provided there was an adequate supply of food. If any particular species increased in numbers to such an extent that they ate up practically all the available food, large numbers of them would die. That would give the animal or plant that provided the food a chance to recover. This increase and decrease in numbers would alternate until a delicate balance had been established.

The development of life on this imaginary island has been described for three important reasons:

1. Although it is possible to keep animals and plants in the laboratory so that practically all of their natural enemies are excluded, this does not occur in nature. If we are to get a true picture of any particular organism, we must study it in its natural environment or habitat. Thus ecology is simply the study of the intimate relations between animals and plants in their own 'homes'.

2. As was pointed out above, only salt-marsh plants would grow on the land in the very early stages. Each particular organism has developed characteristics that enable it to thrive under certain conditions, i.e. it has become adapted to a particular environment.

You know that whales have thick layers of blubber to protect them from the cold, and as they spend the whole of their lives in the sea they have no need of legs. How long do you think a whale would survive if it were transported to a tropical jungle?

3. Finally, in any particular habitat, large numbers of organisms live together in a state of balance.

Ecology is a very large subject, and as this is your introduction to it you cannot be expected to cover the whole field. You should concentrate on these two branches of it:

1. Adaptation to environment. What are the characteristics of any particular organism that enable it to live in the particular habitat you are studying?
2. Food chains. Study the food supply of each animal in order to find out if there is a state of balance in the habitat.

We are not merely going to make a collection of dried leaves but intend to find out why some plants live under the hedge; why the dandelion of the waste patch of land and the dandelion of the grassed playing fields look entirely different; why the periwinkle is able to live above high-water mark; or why the red sea-anemone is found on the sheltered side of rocks.

In the first stages of your field study, when you are making collections, by all means use books, the museum, or any other facility to which you may have access to identify the plants and animals. However, there are practically no books that will describe the habitat you select for your study. You must make your own investigation and endeavour to find your own answers. The remainder of this chapter will give you some guidance and assistance.

EFFECT OF THE ENVIRONMENT

There are many factors to be considered in any one environment or habitat. They are usually grouped under three headings.

A. Climatic Factors

(a) *Temperature.* The effect of high and low temperatures on animals and plants.

(b) *Rainfall.* Some plants will not grow in deserts.

(c) *Wind.* Some young plants cannot establish themselves in very windy situations.

(d) *Evaporation.* Seashore rock pools and swamps can dry out.

(e) *Light.* All plants need light for photosynthesis.

B. Physical Factors

(a) *Slope of the surface* produces slow-moving or swift-flowing water, rapids or waterfalls—animals and plants in swift-flowing water will require adaptations for holding on.

(b) *Aspect*—whether the rocks of the seashore or banks of a stream are shaded or not.

(c) *Type of coastline* to a large extent governs the degree of wave action. However, winds, a climatic factor, may increase this wave action.

(d) *Tides* govern the amount of drying out or desiccation that seashore animals and plants have to overcome.

(e) *Type of substratum*—whether it is rock, shingle, clay soil, or sand. Pipis are found in the sand and not under rocks.

(*f*) *Salinity* or amount of salt in the water. This varies quite a lot in tidal creeks and rivers and most fresh-water animals will die if placed in sea water.

C. Biotic Factors

The effect of other organisms (plants and animals, including man) on plants and animals in that particular habitat, e.g.

(a) Parts of our native bush are being destroyed by deer which eat all the foliage on young saplings.

(b) Diphtheria bacteria produce waste products or toxins which can kill human beings.

(c) Trees produce shade, so that grasses in the immediate vicinity are long and lax-growing.

(d) Water hyacinth grows so rapidly that it can block a stream and convert large areas into swamps.

This list is by no means complete. In certain cases, special conditions will be found, and these must be taken into account in any particular field study. For example, a patch of grass which has regular traffic over it will be quite different from that found in a secluded corner.

Four selected habitats will be dealt with later, i.e. a seashore habitat, a fresh-water habitat, an area of grassland, and an area of native bush. However, before going on to discuss these selected habitats you should study the next section very carefully.

HOW TO CARRY OUT A FIELD STUDY

A. Selection of a Suitable Site

As the field study may extend over a long time, select a place reasonably close to school so that you will be able to visit it regularly during your normal science periods. Do not forget to obtain permission from the necessary authorities if other than school property or land is selected as your field study.

B. Preliminary Work

Before you go out on an excursion, you should have a clear idea of what you intend to do. It is very easy for a field trip to degenerate into a picnic unless full preparations are made. Here are some matters you should discuss beforehand.

1. *Class discussion.*
   (a) What is 'ecology'?
   (b) The nature of the locality that has been selected and some of the environmental factors to be found in it.
   (c) How will you identify the animals and plants you find?*
   (d) *Equipment.* In general you need a notebook, a hand lens, a small paint-brush for picking up small animals, specimen jars or corked test-tubes, quart preserving jars with screw lids, a piece of string about thirty feet long knotted at every six inches, and a foot or metre rule. For collecting insects in ponds or pools you need a dip net which can be made by binding a fine-mesh wire food strainer to a three-foot length of dowel stick. Possibly you will need a larger net, one foot in diameter, which can be made from mosquito netting. A large white enamel collecting dish is also useful, as the white background assists in sorting and identification. A stout-bladed pocket knife will be useful for prizing limpets, etc. off rock platforms. If you choose a pond, a rock pool or a swamp, it would be as well to wear old tennis shoes to protect your feet from cuts which may fester. A suitable container such as a box with a handle will be needed to carry jars or other glassware. This is necessary, particularly when clambering over rocks and stones, as you may slip and injure yourself seriously on the broken glass.

*Suitable reference books will be suggested for each of the habitats described in this chapter. If the school does not possess class sets, it would be advisable for you to buy at least one of them for your own use. Most of the books recommended are relatively cheap. Study your book before you go out so that you will know how to use it to identify your specimens.

(e) *Collection of animals and plants.* The purpose of your field study is to observe and study how plants and animals live together in a particular habitat.

It is not intended that you should make a museum collection of animals and plants. However, it may be necessary to collect some animals, such as insects, and kill them for later study and identification. A safe killing bottle can be made by placing some cotton wool or sawdust soaked in carbon tetrachloride in the bottom of a screw-top jar. Cover the sawdust or cotton wool with a piece of fine gauze or filter paper and keep the lid screwed on tightly so that the jar becomes full of fumes of the gas. For collecting plants and drying them out, use several old magazines, the paper of which is not glossy.

(f) *Preservation of plants and animals.* You may wish to preserve animals and plants for future reference and discussion. The table on page 343 of the Appendix contains details of suitable methods of killing, fixing, and preserving your specimens. Most plants can be preserved in 70 per cent alcohol or 4 per cent formalin, but unfortunately the plants will lose their green colour. It is therefore advisable to preserve them dry by pressing them between pages of non-glossy paper.* Most specimens will require about fourteen days' pressing. Each day they should be taken out, exposed to sunlight, and then put back between different pages of the old magazine or paper you are using.

(g) *Plan of the locality.* Use your thirty-foot line or a rule to measure the size of the area you have selected. Now divide it up into small sections which can be studied by a group.

It is advisable to draw a map of the whole area so that you can show the position of the habitat relative to roads, bush, streams, lakes, and ditches. In addition, you must make a large sketch of your own area so that you can record the positions in which you find various specimens. Take a camera with you so that you can photograph the area you are studying.

2. *Group work.*

The class should be divided into groups, each with a suitable leader. Each group can be given a specific problem to solve, or particular area to study. Group work promotes discussion. All groups should report back to the class so that a complete picture of the habitat can be discussed and recorded by all.

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*Make sure there are plenty of pages between specimens as thick stems may press through and mark the specimens lower down in the pile.

3. *Exploratory expedition.*
   It is advisable that the group leaders, under the guidance of the teacher, should make an exploratory expedition before the class is taken out.

4. *Aquariums and terrariums.*
   Aquariums and terrariums should be set up and ready to receive specimens on the return of the first class expedition. Details of setting up aquaria are included in the Appendix on pages 433-5 of *General Science*. Details of how to set up a terrarium will be found in the Appendix of this volume (p. 342). It is very difficult to repeat exactly the conditions found in the natural habitat. However, aquariums and other laboratory work will allow you to observe more closely how insects, etc., breathe and move, and possibly feed and reproduce. Of course, any results obtained in the laboratory must be rechecked in the natural habitat.

5. *Conservation.*
   When you are collecting plants or animals, do not collect more than is absolutely necessary. The same pool or grassland may have to be used by perhaps ten other classes, not only this year but next year. When you drag the bottom of a pond, pick out a representative sample of each organism and then return the remainder to the pond.

C. Type of Records

The type of record will vary with the habitat but a suggested form is given on page 43.

Other headings may be needed, as respiratory and feeding habits will not apply to plants. However, the record should be such that the last stage of any field study or ecological survey can be discovered. This is mainly the study of the plants' and animals' structure in order to determine how they are adapted to their environment.

D. Stages in any Field Study

(a) Draw a rough sketch of your area marking in the location of your habitat with other relevant features, e.g. trees surrounding a pond, beds of seaweed near a rock pool, entry of sewage into a creek, river or the sea, well-worn tracks across pasture land, etc.

(b) Note the factors which are relevant in the habitat you are studying, e.g. drying out and wave action are most important in a seashore community and type of soil in a grassland community.

FIELD STUDY RECORD

HABITAT: *Rock pool*

DATE: *19th June, 1958* TIME: *2.30 p.m.*

CONDITIONS: *Overcast; almost low tide; no wind; little wave action*

ANIMAL	LOCATION	RESPIRATORY MECHANISM	LOCOMOTION	FEEDING HABIT	FOOD OF	SPECIAL NOTES
LIMPET	*On rocks about mid-tide.*	*Gills in the mantle cavity.*	*Moves by a foot; may move up to 3 ft away from the limpet 'scar'.*	*Feeds on living seaweed.*	*Whelks*	*Exactly fits the rock so as to prevent drying out.*

SUGGESTED RECORD FORM

(c) Collect and identify organisms. Note the relative numbers of each type of organism that you find, keeping in mind the factors which may govern this distribution.

(d) Note how each organism feeds, breathes, and moves. This may require further research in the laboratory.

(e) Complete your record form.

(f) From your field work and laboratory aquariums and terrariums, study how the animals and plants in the different habitats feed and how they live together. Try to work out what might be called food chains. Examples of food chains in different habitats are: limpets feed on growing seaweeds and torn-off drift weed, while the whelks feed on the limpets; microscopic plants are the food of caddis-fly larvae, while these larvae in their turn are eaten by dragon-fly nymphs, which are eaten by fish.

This last stage in your field study of a community will require very close observation and deductions. Here is your challenge, and in accepting the challenge we hope you will learn that the different animals and plants are not isolated organisms but are all parts of a habitat or environment to which they must show adaptation. All animals and plants in a community influence one another in the competition for food and where and how they live.

Some typical types of field studies will now be dealt with. They may help you in the study of some of the problems which will confront you when you go out into the field to make your own investigation.

SEASHORE FIELD STUDY

Those of you who are able to study a seashore community are indeed fortunate. Here you will find a wealth of plants and animals which show adaptation to their particular environment, and you will find these animals and plants within a very short range—namely, between low and high tide water marks.

Factors to be considered particularly in a rock pool are:

1. *Type of sea bottom.* Perhaps the first thing to consider in environmental conditions is the type of sea bottom, i.e. rock, sand, or shingle. It is almost certain that you will not find pipis on a rock bottom nor will you find sea anemones on a sand bottom. The type of rock will also determine whether there are long, smooth, sloping faces, or splintered, large rectangular blocks which provide shelter from the dashing waves. Size of the sand grains may

govern whether the sand is quick-drying or slow-drying. The presence of pebbles may make it more difficult for the animals to burrow.

2. *Desiccation or drying out.* Desiccation is brought about in the first instance by the tides, but this drying out may on the one hand be increased by high temperatures and winds, and on the other hand lessened by spray.
3. *Temperature.* The temperature of the water may affect the distribution of some animals and plants along the New Zealand coast line.
4. *Light.* Many animals are found only on the shaded side of rocks, and some will avoid strong sunlight altogether. This point is worth remembering, and, if possible, a cloudy day is best when planning your trip to the seashore as the animals then move about more freely.
5. *Degree of exposure to waves and pounding surf.* Obviously, delicate organisms, like sea anemones, could not live on rock exposed to the surf.
6. *Chemical condition of the water.* Some enclosed pools will have a high salinity (or percentage of salts) which will be fatal to some animals and plants. Sewage can also be fatal to some organisms, although others, such as *Ulva* or sea lettuce, abound where this is present.
7. *Local conditions.* Warm water from the power house at Evans Bay, blood and other waste products from the meat works at Ngauranga and Petone, dyestuffs and other material from the woollen mills, are all discharged with other waste products into the Wellington harbour. Such conditions must be considered in any field study, particularly if your rocks and pool are near to the source of entry.

(*a*) SAND-SHORE COMMUNITY

What appears to be a lifeless expanse of sand will reveal, on closer examination, a variety of animals adapted to their environment. The best time to do your field work is when the tide is coming in. As the tide comes in, the animals which have burrowed into the sand to escape drying out will come to the surface. Stretch a piece of the six-inch knotted string from high-water mark to low-water mark, and carefully dig in the sand to find the different types of organism which make each part their home. Take areas of one foot square along this line, and count the numbers of each kind of animal in this area. Plot a series of curves to show numbers per square foot

and distance above low-water mark (see p. 47). Do not include single specimens, as these may have drifted in, and will not be part of your sand-shore community.

Sand can retain water for long periods after the tide has receded, and even then it rarely dries out below a depth of six inches. The ability to burrow in the sand to escape drying out also solves problems of intensity of light, temperature changes, and protection from beating waves.

Seaweeds cannot burrow into the sand and they do not have roots like land plants. There is no firm base for them to attach themselves to, and hence they are at the mercy of the waves. Very few seaweeds —if any—are found living on the sand.

Where the sand has been covered by the incoming tide, look for worm-casts. These are similar to those found on your lawn. They are made by worms which live in burrows and feed on the sand. Near the worm-casts you will notice a depression. This is the head end of the worm's burrow, while the worm-cast denotes the tail end. See whether you can find out what causes the depression. Be extremely careful when attempting to get a worm out of the sand. Worms are very delicate organisms and will break easily. Other worms build tubes of sand grains into which they retreat at low tide, and still others carry this tube about with them. If you are very careful in your paddling you will see the head or tail end of the worm emerge from its burrow or tube.

Other animals found in the sand are mainly bivalves (such as pipis, cockles, tuatuas, toheroas, mactra), burrowing prawns and crabs, cucumber, and some fish such as 'toe biter'. The majority of these animals obtain their food from the water, which contains minute plants and animals that may be siphoned out when the tide is in. Starfish are carnivorous and feed on molluscs, crustaceans, and worms. The 'toe biter' lies almost completely buried in the sand. On one occasion a specimen eighteen inches long was observed in twelve inches of water with only the eyes protruding above the sand. All the animals found in the sand-shore community, whether they are worms, bivalves or fish, have a common process of burrowing into the sand which provides them with protection, and sometimes with food.

(*b*) ROCK-SHORE OR ROCK-POOL COMMUNITY

In any seashore community, a wealth of fauna and flora will be found adapted for life on rocks or in a rock pool. The variety of species will far surpass that of life found upon and within the sand.

The best time to study a rock pool is on a cloudy day when the tide is going out. Then you can observe the gradual emergence of the different zones.

We can divide a rock shore or pool into three main zones. The area farthest up the shore will be covered only at high tide, and animals or plants living in this upper zone must be able to withstand long periods of drying out. The mid-tide zone is covered by water for a large proportion of the time, but fauna and flora living there must still be able to withstand the lack of water for several hours at a time. The lower zone is covered with water most of the time, except during exceptionally low spring tides. Each of these zones can be clearly marked off by the distribution of animals and seaweeds.

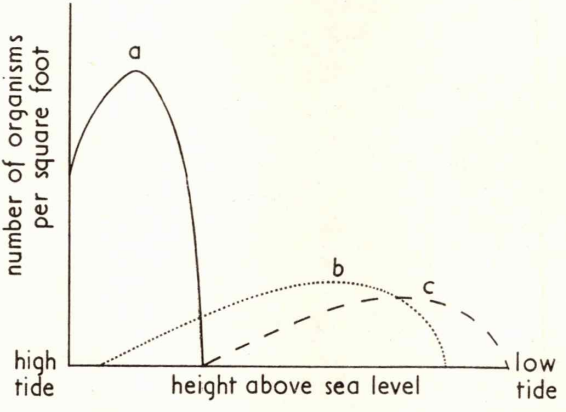

FIG. 19. Graphical presentation of frequency of occurrence of typical organisms in a rock-shore community: (a) Small periwinkle; (b) Limpet; (c) Lined whelk.

Stretch the piece of string knotted at six-inch intervals across a rock pool or down a rock shore. Measure the vertical height of the animals and plants above sea-level at low tide, and also count their numbers per square foot. As before, draw graphs to show the distribution of species with relation to sea-level at low tide. Do not forget to look under the rocks, as many animals shelter there from the waves and the sunlight.

Draw a profile or section as shown in Figure 20 and indicate where organisms are found. Do not forget to indicate which is north and the scale of your map.

Probably the most important consideration in the distribution of animals and plants in a rock-shore or rock-pool community is desiccation, and in each of these three zones there will be found animals and plants which have adapted themselves to their environment.

EXPERIMENT *To study the drying out of seaweeds.*

Weigh samples of seaweeds from different zones, and then spread them out in the open on a dull, overcast day for three hours. After they have been weighed again, calculate the percentage loss in weight.

Corallina and *Carpophyllum* lose from 40 per cent to 50 per cent of their weight. This shows an interesting correlation with their habitat, as they are nearly always completely submerged. *Hormosira*, on the other hand, loses very little weight.

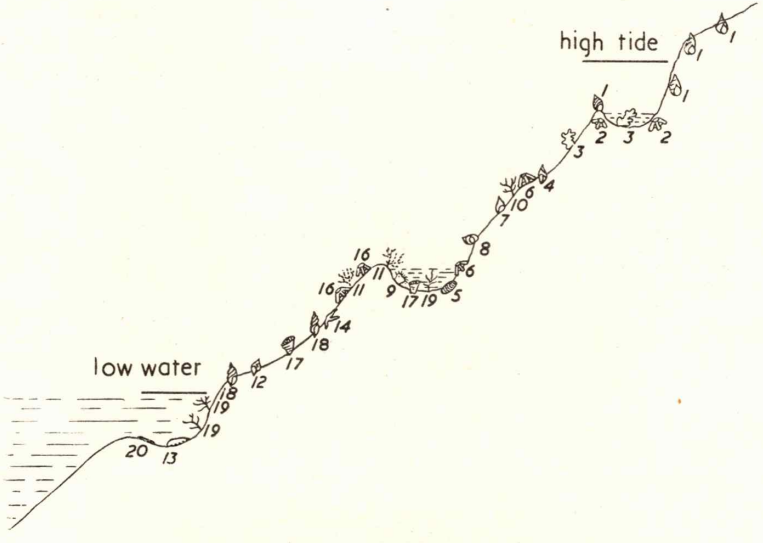

FIG. 20. Profile or section of a seashore with rock pools.

1. Periwinkle
2. Acorn barnacle
3. Sea lettuce
4. Limpets
5. Snake-skin chiton
6. Barnacles
7. Top shells
8. Cat's eye
9. Sea anemone
10. Green seaweed
11. Hormosira
12. Winkle
13. Paua
14. Starfish
16. Barnacles
17. Corallina
18. Whelks
19. Red seaweed
20. Sea slugs

Dry air and bright sunlight are not natural elements of truly marine animals, and therefore few specimens will be found in the upper zone. Acorn barnacles, mussels, true periwinkles*, and the green seaweed *Ulva* or sea lettuce are the characteristic organisms of the upper zone. In general, the green seaweeds are more like land plants, as they are exposed to direct sunlight for the greater part of the day. The animals are dependent upon the seawater for their food,

*Top shells and cat's eye are frequently called periwinkles.

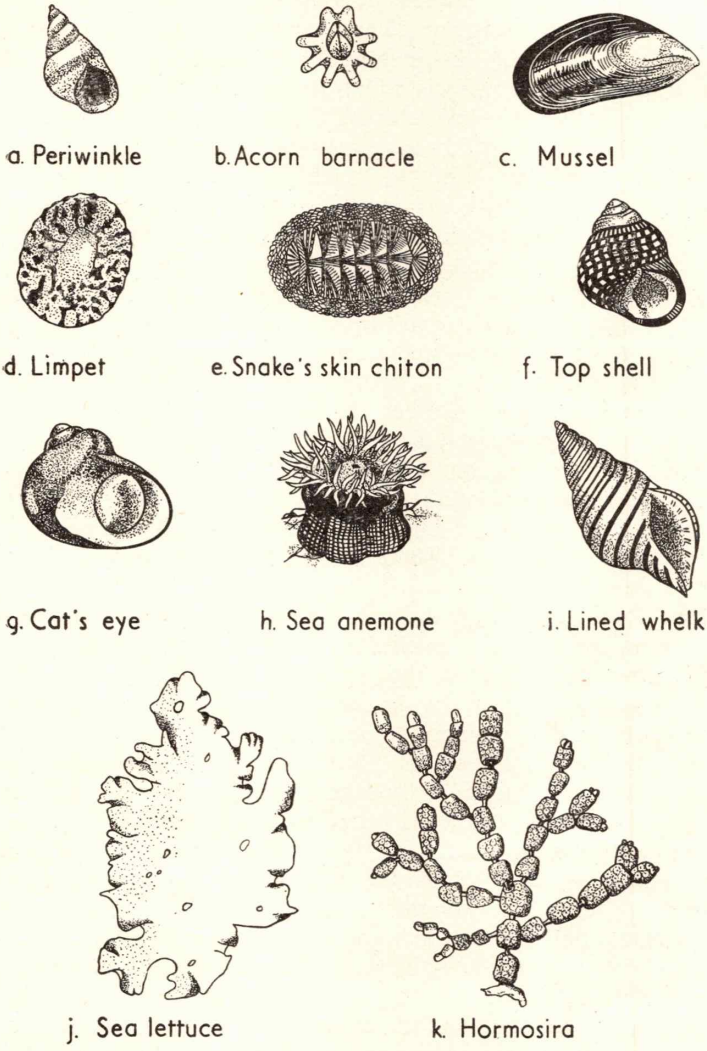

FIG. 21. Common animals and plants found in a seashore community.

but must be able to conserve water for long periods. The periwinkle has an operculum or thin shell-like plate on its foot, and when it withdraws into its shell the operculum fits tightly within the shell, this being further sealed off by mucus. Periwinkles have remained

alive for as long as three weeks in completely dry air. The barnacle, which is shaped like a volcano, has several plates that fit together like trapdoors and close up the opening so as to conserve the water they have trapped inside. Mussels, which are bivalves, close the two valves or shells together. These valves fit together exactly, protecting the delicate internal organs. In comparison, the fan shells and scallops which you may pick up on the beach have large gaps between the edges of the closed shells. These animals live in very deep water and never have to avoid desiccation. Barnacles, mussels, and periwinkles feed on lichens and the plankton* in the sea-water.

In the mid zone, brown seaweeds† are common, but some green ones, such as *Codium enteromorpha*, are also found in this zone. *Hormosira*, *Scytothamnus*, and *Ecklonia* are all common brown seaweeds found in this area, and extend into the lower zone. Examine *Hormosira*, or necklace seaweed. Squeeze one of the beads between your fingers. Notice that it is filled with a sticky fluid which prevents the plant from drying out when the tide is out. These beads filled with fluid serve an altogether different function from the floats of *Carpophyllum*, which are filled with air to keep the seaweed near the surface of the water. These seaweeds with floats grow in very deep water. Sheltering beneath the *Hormosira* and other seaweeds will be found cat's eyes and top shells. These univalves have an operculum, but it is not as effective as that of the periwinkle, and experiments conducted in the laboratory have shown that these animals will not exist in dry air for as long as the periwinkle of the upper zone. Other common animals found in this zone are the limpet, the red sea-anemone *Actinia*, crabs, snake-skin chiton, hermit crabs, and starfish. All of the animals are able to resist desiccation, or can move to the shelter of rocks and seaweeds. The edge of the limpet's shell exactly fits the particular patch of rock which it chooses as its home. When the tide is in, the limpet moves about in search of food, but when the tide goes out it always returns to this one spot and pulls its shell tightly down into the rock. This not only overcomes drying out, but will protect the limpet from dashing waves. In time, this may wear away the rock, leaving a 'limpet scar'. Mark some limpets with paint and see how far they move from their home. See if you can find how each animal in the mid zone overcomes desiccation and danger from dashing waves and surf.

In the lower zone, common seaweeds are *Glossophora*, *Halopteris*, *Splachnidium*, and *Lessonia*. Red seaweeds such as *Champia* and the

*Plankton is the name given to minute organisms which are present in all sea-water.

†For identification of seaweed, refer to *Post-Primary Bulletin*, Vol. 2, No. 13, 'Seaweeds'.

carrageens are found in the deeper part of the pools, and are seldom exposed except at extreme low tides. Animals found in this zone are lined whelks, pauas, sea-slugs, sea-urchins, lobsters, starfish, crabs, and the coiled worm shell.

All plants manufacture their own food by the process of photosynthesis, but animals may be herbivorous or carnivorous, or may feed on the plankton. One example of a food chain (see p. 44) has already been given. Most bivalves feed on the plankton, and are themselves eaten by other carnivorous animals. See how many food chains you can discover, and you will learn that *Hormosira* and limpets are not isolated organisms but are parts of a seashore community.

(*c*) Estuarine Flat

The factors controlling the distribution of plants and animals in an estuarine flat are similar to those in a seashore community. However, the factor of salinity, which varies very little in a seashore community, is the predominant factor in an estuarine flat. Wave action is almost non-existent and for this reason green seaweeds are commonly found in an estuarine flat. A small pebble or shell is sufficient to act as an anchor to which the seaweed can attach its holdfast. The distance that the tides advance up a river varies not only with spring and neap tides but also with the amount of rainfall. As this rainfall is greatest in winter, you may observe a seasonal migration of life in the estuarine flat. Normally sea water has a salinity of 35 parts per thousand, but in an estuary* it may be as low as 20 parts per thousand. This difference will tend either to dehydrate the animal, which will lose its body fluids, or cause the animal to swell up because extra water enters its body. This change in salinity is fatal to most truly marine life and to most truly freshwater organisms. In an estuarine flat, worms and other animals can avoid the change in salinity by burrowing, just as they do in a sandshore community.

With the increased rainfall and consequent decreased salinity in winter there will be an increase in the amount of material carried in suspension in the water. This not only affects the intensity of light —in heavy flood the intensity of light is reduced to one per cent within about twelve inches—but also the delicate feeding and breathing organs of some animals will be clogged up with the very fine mud.

Most animals in an estuarine flat live below the mud, and you will possibly find worms, crabs, mud snails, mud-flat top shells, cockles, and starfish. Because of the many and varied problems, it is not recommended that you study an estuarine flat as a field study.

*An estuary is the mouth of a large river which is influenced by tides. Thus the conditions may vary from fresh water to salt water twice a day.

You would be wiser to take either of the neighbouring regions—fresh-water ponds and streams, or seashore communities.

BIBLIOGRAPHY FOR SAND-SHORE AND ROCK-POOL STUDY

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Native Animals of New Zealand . . . . A. W. B. Powell
Post-Primary School Bulletin (Vol. 2, No. 13),
'New Zealand Seaweeds' . . . . Lucy B. Moore
These three books are essential for identification; useful as class sets.
New Zealand Nature Study . . . . Wm. Martin
Useful for identification and general nature study.
The Sea Shore . . . . . C. M. Yonge
Australian Sea Shores . . . . . W. J. Dakin
Life of the Shore and Shallow Sea . . . . D. P. Wilson
Animal Ecology . . . . . W. H. Dowdeswell
Fresh-water and Salt-water Aquaria . . F. G. W. Knowles
These books are useful for reference and general background.

FRESH-WATER STREAM OR POND STUDY

The more important environmental factors to be considered in any fresh-water study are:

(1) *Rate of flow of water.* This is probably the most important factor affecting the distribution of animals. If the stream is rapid-flowing there will be fewer *plants* and therefore less *food* for the animals. Although some animals may be carnivorous, they feed on other animals which are herbivorous. In general the amount of fauna and flora found in a pond or slow-moving stream (less than one foot per second) far surpasses that of a swift-flowing stream. In addition, the animals in swift water will need to have developed adaptations for hanging on, so as to prevent their being washed down stream, e.g. some species of caddis-fly larvae live in a case which is anchored to the rock; or the insects may reduce the body area exposed to the current and adopt a flattened form, e.g. may-fly nymph; or they may simply shelter under stones, e.g. fresh-water shrimps.

(2) *Type of substratum.* The banks and bottom of the stream may be mud, sand, shingle, or smooth rock, or mixtures of these. Some insects will soon die if placed in the mud, because their gills or spiracles soon become clogged up with the particles of silt.

(3) *Temperature.* Almost all pond life is cold-blooded, and the fewer hours of sunshine and lower temperatures in winter have a definite effect on pond life. First, most reproduction ceases in winter. Second, the activity of the pond may be reduced by the low temperature to such an extent that they may adopt some hibernating phase.

For this reason it is best to start your field study in the spring or summer, when the waters are warm and the various forms of animal life have emerged from the homes they have made in the mud of the banks or bottom of the pond.

(4) *Rainfall.* Lack of rainfall in the summer months could possibly cause the pond to dry up. This would probably destroy almost all the life of the pond. On the other hand, excessive rainfall, or more important, excessive run-off will affect the animals which live in streams or ponds, as the water will be full of mud and silt.

(5) The *chemical* condition of the water has an important bearing on the life of a pond or stream. Animals must have oxygen to carry out respiration and obtain energy for the normal body processes. The surface waters in contact with air naturally contain more dissolved oxygen than the deeper water. Some animals live on the surface and breathe air, e.g. pond skater, whirligig beetle; others come up to the surface to obtain air, e.g. water boatman, pond snails; some live below the surface but have breathing tubes or siphons which reach the surface, e.g. the hover-fly larvae, which is one inch long, has a breathing tube six inches long; others breathe through gills, e.g. fish, may-fly nymphs, caddis-fly larvae. Those animals which live in the mud at the bottom of the pond must filter the water before it is passed over the delicate gill structure which would soon become clogged. More sunlight in summer means greater plant growth, which increases the oxygen in the water, and some animals will be found living amongst the pond weeds, which provide them not only with food but also with oxygen. Sewage and carbon dioxide will affect the acidity of the water.

(6) The effect of other animals and plants.

Other minor environmental factors may affect the pond life of your particular field study. The main factors to keep in mind, however, are rate of flow of the water, oxygen content, acidity, and type of substratum.

The best method of analysis for a stream or pond is by drawing a profile or section (*Fig. 22*) of the pond or stream. Peg the thirty-foot knotted string across the surface of the pond or stream, and measure the depth at each knot with the ruler. Draw a scale diagram of the pond or stream, and mark in the positions of all animals and plants collected. Collect animals and small plants from the surface of the water, from below the surface, and from the bottom of the pond or stream. Also collect animals and plants from the banks of the pond, from in amongst the weeds, and from under and on top of rocks. Dig some of the plants out of the bank, making sure you have plenty of soil around the roots. When you are making your collection, note any factor which might affect their distribution. At all times in your

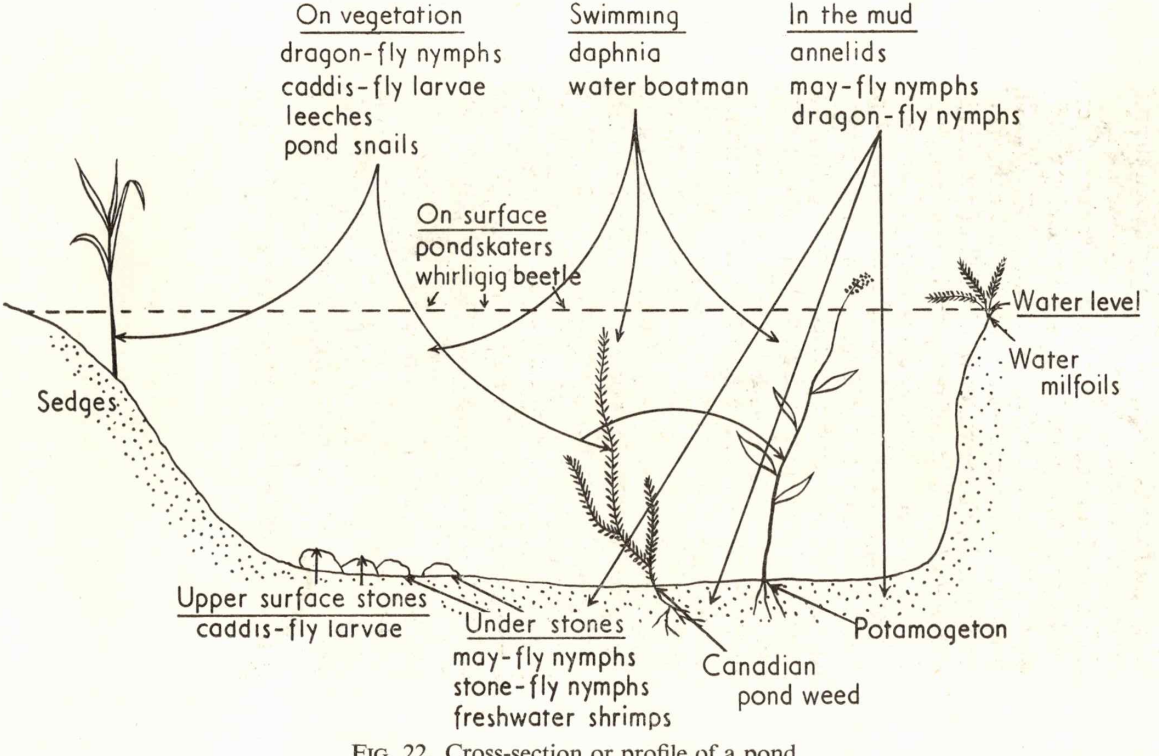
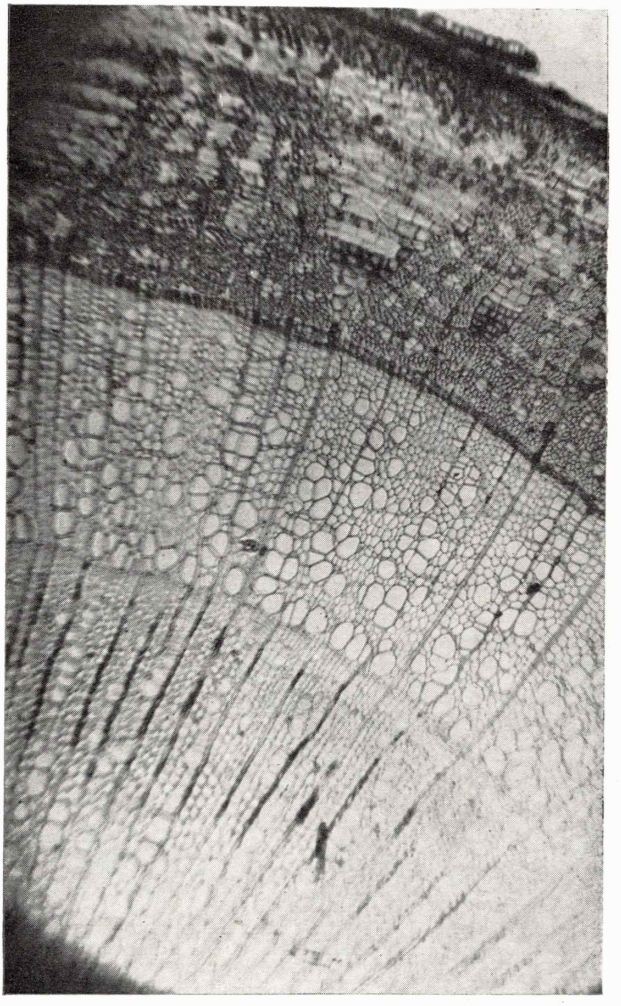
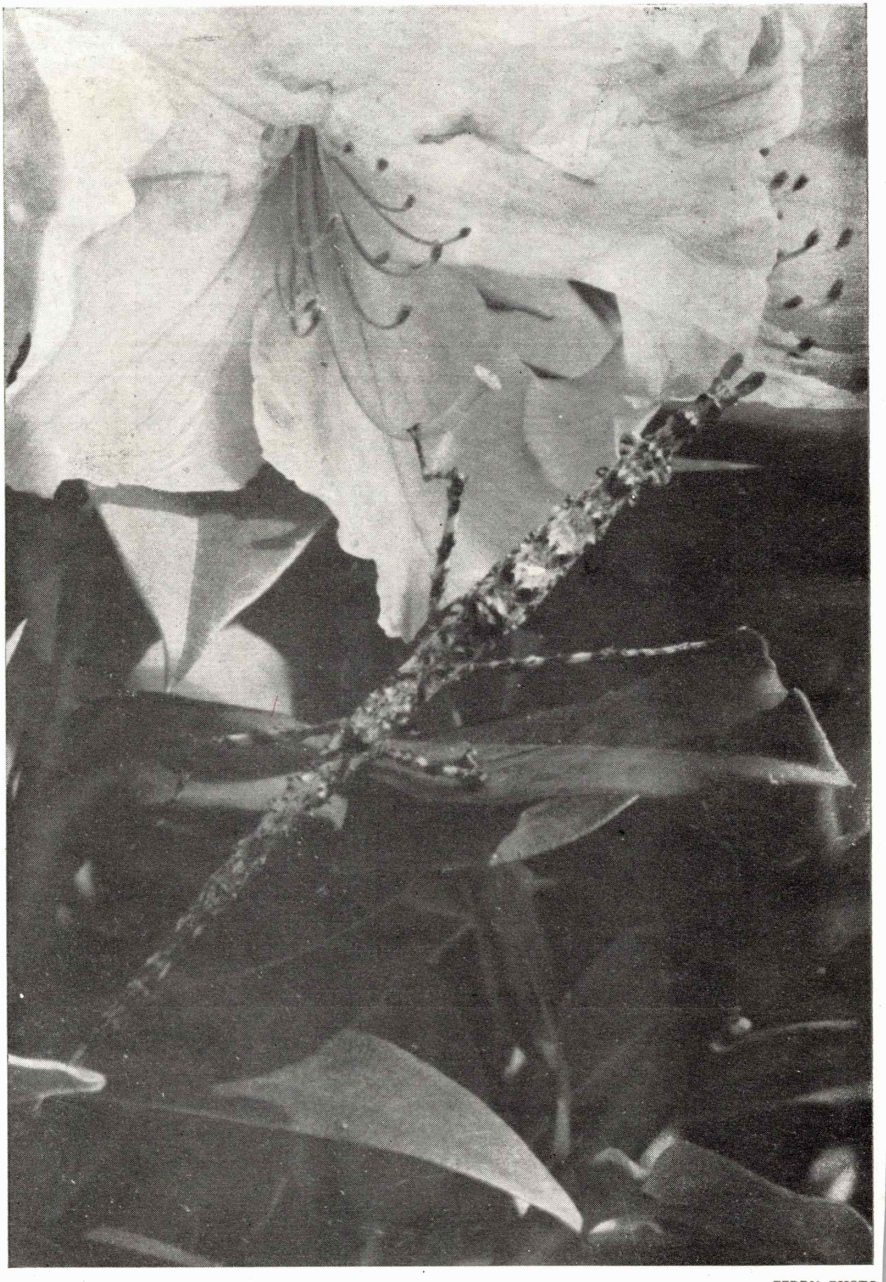


FIG. 22. Cross-section or profile of a pond.



1. Microphotograph of a cross-section of a woody stem (Page 6)



PERRY PHOTO

2. A stick insect (Page 29)

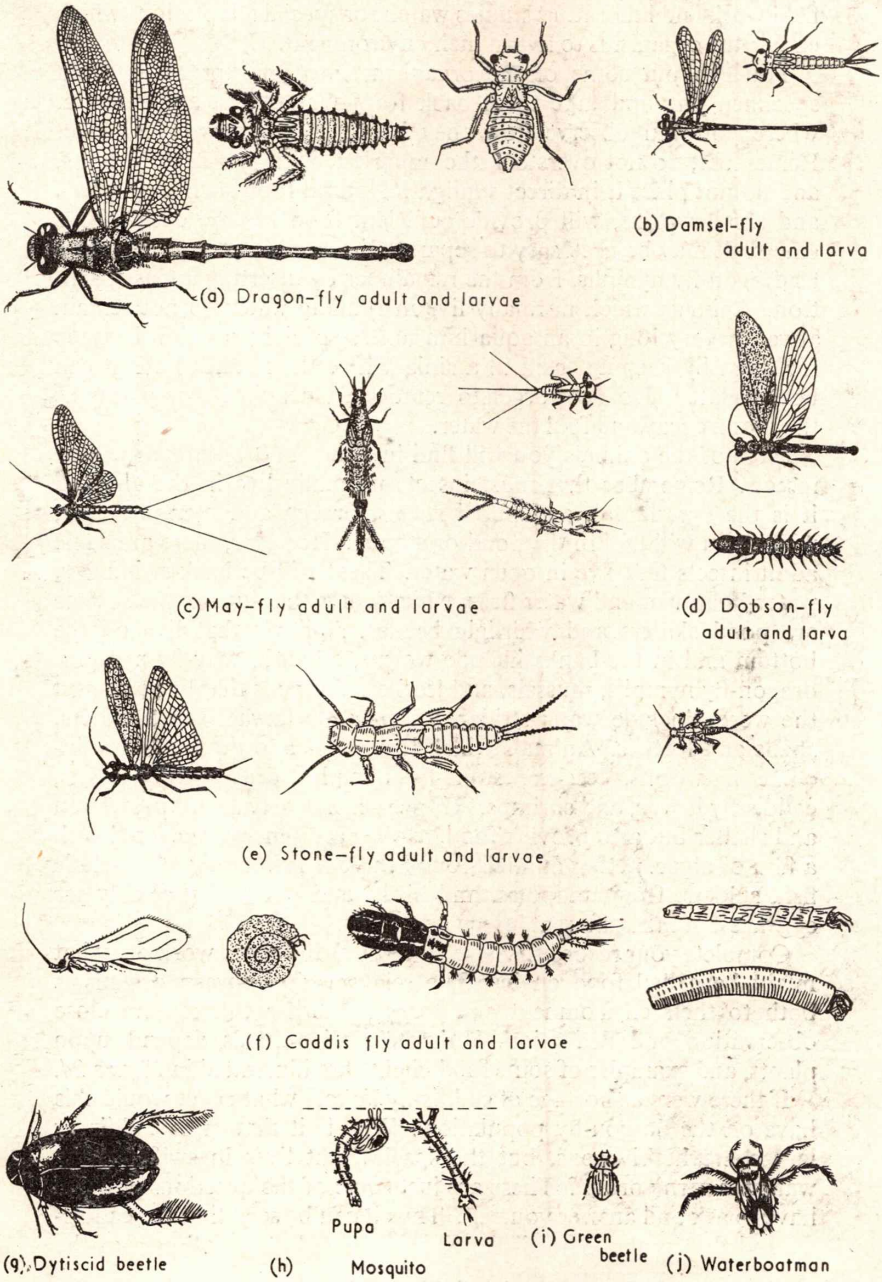


FIG. 23. Common animals found in a fresh-water community.

field work and laboratory studies watch for special adaptations which enable the organisms to live in their environment.

You can put some of the organisms into your preserving and specimen jars and take them back for your aquaria and terraria, where you can observe how they breathe, and move, and feed. Remember, do not overstock the aquarium with animals or plants, and do not place it in direct sunlight. Natural food such as *Daphnia* and small worms, will provide sufficient food for the carnivorous eaters. It may be necessary to separate the carnivorous species, such as dragon-fly nymphs, from the remainder by inserting a glass partition. Animals which normally live in running water do not remain alive for very long in an aquarium unless special provision is made for them by keeping them in a sink, where the natural habitat can be simulated. Do not forget to remove dead animals or plants as they soon decay and foul the water.

Most of the animals you will find in your pond or stream will be insects. Remember that most insects normally live in the air, and it is the egg, larval, and pupal stages, or egg and nymph stages, which you will find in the pond or stream. However, there are some adult insects that live in open water. These will be back-swimmers, water-boatmen, and water fleas, while others that live on the surface are pond skaters and whirligig beetles. Animals that live on the bottom and in the banks include worms, crayfish, may-fly nymphs, dragon-fly nymphs, mussels, and leeches. Animals that live amongst the weeds include water-strider, water-beetle larvae, water-spiders, snails and leeches. Animals which live under and on the stones include flatworms, leeches, stone-fly nymphs, dragon-fly nymphs, caddis-fly larvae, and shrimps. The stones not only afford protection and shelter but also provide food, as they are generally covered with a film of algae. Other animals found in your field study will include fish, spiders, frogs, tadpoles, and birds, and you will probably see egg masses of the different insects and frogs.

Complete your record sheet (see opposite) and try to work out what might be called food chains. The relationship between organisms both to their environment and to one another will require close observation and deduction. Ultimately all animals depend upon plants, and examples of some food chains are illustrated in *Figure 24.*

If there were a shortage of caddis-fly larvae, what effect would this have on the dragon-fly population? Why is it that most caddis-fly larvae are herbivorous, but the species that lives in swift-flowing waters is carnivorous? These are just some of the questions you will have to ask and answer yourself. Thus it can be seen that the caddis-fly and the trout are not isolated organisms, but are all part of the pond or stream community. All animals and plants in a community

FIELD STUDY RECORD

ANIMAL	LOCATION	RESPIRATORY MECHANISM	LOCOMOTION	FEEDING HABITS	FOOD OF	SPECIAL NOTES
DRAGON-FLY NYMPH	*Among the rocks and plants in slow-flowing streams.*	*Gills in a special chamber at the rear end of the animal.*	*Crawls with its legs, and jet propulsion when water is shot out of the abdomen.*	*Carnivorous; feeds on caddis-fly larvae and may-fly larvae.*	*Fish*	*Very much enlarged hinged lower lip or mask which bears two pincers at the end.*
WATER-BOATMAN	*In the open water of slow-moving streams or ponds.*	*Comes to the surface and traps beneath the wings bubbles of air which enter the body through spiracles and tracheae.*	*Swims with great agility. One pair of legs fringed with hairs and used as paddles.*	*Small nymphs of may-flies, other aquatic larvae, and* Daphnia.	*Birds*	*Boat shaped; swims wing - side uppermost.*

FIELD STUDY RECORD SHEET

influence one another in their competition for food, and where and how they live.

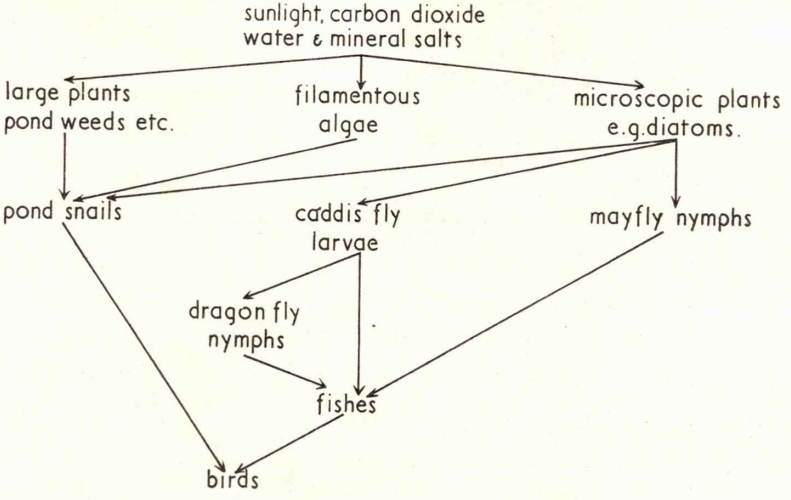


FIG. 24. Diagram of a food chain.

BIBLIOGRAPHY FOR FRESH-WATER FIELD STUDY

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Native Animals of New Zealand . . . A. W. B. Powell
Post-Primary School Bulletin:
Vol. 4, No. 12, 'Water Plants' . . . Ruth Mason
Vol. 3, No. 4, 'Sand-Dune Plants' . . Lucy B. Moore
These books are essential for identification. Useful as class sets.
New Zealand Nature Study . . . . Wm. Martin
A Guide to Fresh Water Biology . . James G. Needham and Paul R. Needham
Animal Ecology . . . . W. H. Dowdeswell
Pond Life (Puffin Picture Book 93) . . Jean Gorvett
Fresh and Salt-water Aquaria . . . F. G. W. Knowles
These books are useful for reference and general background.

GRASSLAND FIELD STUDY

If your school is not near the sea coast or a fresh-water stream, and you are unable to carry out regular visits, the most suitable community for you to study will probably be a patch of grassland. The three principal types are:

1. A school lawn or playing field;
2. A grazing paddock on a farm;
3. A patch of wasteland.

The main factors which determine the type of plants in a grassland are:

1. CLIMATE

(a) *Temperature.* Temperatures above 90°F favour the growth of paspalum, while ryegrass, white clover, cocksfoot, and subterranean clover will grow best if the temperature is 70°F.

(b) *Shade.* Some grasses are shade-loving, and some are shade-avoiding. If a playing field is kept mowed or a pasture is close eaten, ryegrass will be dominant, but along the edges where the mower cannot reach, or along the fence-line, or under trees, cocksfoot and prairie grass are the dominant species. Shade also affects the rate of tiller* formation. Cocksfoot, paspalum, and lotus major spread more quickly in the shade than ryegrass and white clover.

(c) *Rainfall.* Most areas in New Zealand receive sufficient rainfall to grow any grass providing soil fertility is right. Parts of Canterbury and Otago need irrigation to grow permanent ryegrass pastures. However, you may find in your field study that where there is exposure to a drying wind, or on well-drained soil over shingle, the dominant species is browntop. In sandy soils that dry out very quickly those grasses which have underground stems, e.g. the twitches, will tend to survive.

2. SOIL FERTILITY

(a) Ryegrass, timothy, cocksfoot, and Yorkshire fog tend to grow in the more fertile soils, while browntop and danthonia will be found on the poorer soils.

(b) Some grasses prefer acid soils, whereas others flourish in neutral or slightly alkaline soils. The addition of lime is the most common method of reducing the acidity of a soil.

Most of the essential elements — nitrogen, phosphorus, potassium, sulphur, calcium, and magnesium — are more soluble in neutral soils. Their solubility decreases as the acidity of the soil water increases.

3. EFFECT OF OTHER ORGANISMS

A. PLANTS. Dandelion in a lawn spreads out and shades the finer grasses, eventually killing them, whereas in a hay paddock it cannot compete with the grasses and consequently may be overgrown and killed.

*Tillering is the production of lateral shoots and may be artificially increased when the main bud is cut by mowing or crushed by pressure such as rolling.

B. ANIMALS

(a) *Man.* Application of artificial fertilizers, e.g. sulphate of ammonia, can stimulate grasses and kill flat-leafed weeds. Phosphates increase the growth of clovers, which by root nodules increase the nitrogen content of the soil, thus increasing soil fertility and the proportion of ryegrass.

If a playing field is kept closely mowed, weeds such as dandelion, buttercup, and daisy will be found in the field. Moreover, the dandelion adapts itself to the environment most successfully, in that the crown is well below the level of cutting.

(b) *The grazing of animals.* The grazing of sheep and cattle, with the resultant return of faeces and urine to the soil, can raise the soil fertility and the pasture content. Sheep graze the pasture evenly—almost to ground level—and spread their faeces evenly. The pasture will be probably dominantly ryegrass. Cattle, on the other hand, do not graze so closely, and there is an uneven spread of faeces. The resultant pasture will be uneven in distribution of species.

(c) *Worms.* Worms increase aeration and improve soil structure. In recent experiments, where turves containing worms were transplanted throughout a farm, the pasture rapidly changed from a browntop and danthonia pasture to a ryegrass pasture.

After you have decided on the locality you intend to study, it will be advisable to take a number of small areas scattered irregularly throughout the grassland. This can be done by throwing wire circles one foot in diameter in different directions. The areas should be numbered and their approximate positions marked on a plan of the field.

Your first job will be to identify the grasses and weeds in each area. At the end of this section you will find a list of textbooks which will help you to do this. Count the number of plants of each type in each circle and also the approximate area each plant covers. Some grasses spread out and cover more ground than others, and therefore make up more of the grassland than those that do not tiller.

Having identified and analysed your grassland community, there are many experiments you can carry out to determine the effects of changed conditions.

1. Application of different fertilizers, e.g. superphosphate, sulphate of ammonia, liming.

2. Cutting one area very close, another less frequently, and leaving another uncut. If a pet lamb can be brought to school the effect of grazing compared with mowing can be investigated.
3. Rolling the area or beating it with the back of a spade to show the increase in tillering.
4. Forking the area.
5. Transplanting turves containing worms.
6. Cutting one area by hand and removing the clippings. Grazing a similar area by a pet lamb, and leaving the faeces and urine.
7. A special project in a patch of wasteland is the study of a succession to a climax. Start with a bare piece of ground. Note the first plants which colonize the area, and watch the appearance of new ones. Finally, compare the final or climax community with your early records.

You probably have been asking yourself what is the purpose of all this ecology? Man is just one of the factors in any community, but if he is to maintain a high standard of living he must know all about the other factors, so that he may control or attempt to control the environment of other animals and plants in that community. This control of other factors is more clearly shown in a grassland community than in other field studies and the application of this knowledge to New Zealand pastures is of vital importance.

BIBLIOGRAPHY FOR GRASSLAND FIELD STUDY

Pasture Plants and Plants of New Zealand . . F. W. Hilgendorf
Weeds of New Zealand . . . F. W. Hilgendorf
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Grasses of New Zealand . . . . H. H. Allan
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Grasslands of New Zealand . . . E. Bruce Levy
Useful for reference and general background.

FOREST FIELD STUDY

New Zealand forests are of two main types, sub-tropical rain forest and sub-antarctic rain forest. The rain forests of the world are, with the exception of New Zealand and Chile, confined to the tropics. The forests of other countries in the temperate zones are deciduous. In addition, the forest of New Zealand has developed and reached maturity or a climax without the presence of browsing animals, which, since the presence of the white man, have completely changed the character of a forest community.

The main factors to be considered in any forest community are:

1. *Temperature.* A change in the forest is seen as we go south from Auckland to the Bluff. This is brought about by a decrease in temperature. But the gradual alteration in the forest species brought about by a change in latitude is observed in a few thousand feet by a change in altitude.
2. *Rainfall.* Most areas in New Zealand receive sufficient rainfall to support a sub-tropical rain forest. But on the drier ridges the sub-antarctic forest is dominant.
3. *Soil.* The original soil can be altered so much by decaying organic matter that with few exceptions this factor is relatively unimportant.

Minor factors which you may possibly have to consider are aspect, proximity to the sea, swamp conditions, and topography. The main factors are latitude and altitude with the resultant changes in temperature and rain. The characteristics of a sub-tropical rain forest are that, (a) most trees are evergreen, (b) there is a dense undergrowth of small trees and shrubs, (c) climbing plants, mosses, and ferns abound. The characteristics of a sub-antarctic rain forest are, (a) its open appearance, in that generally only tall beech trees are present, (b) the absence of undergrowth of shrubs, (c) the presence of very few species of ferns or climbing plants.

Method of Study

1. *Factors of the environment.* If possible, choose an area of bush where you can observe the change from sub-tropical rain forest to sub-antarctic.
2. *Identification of the species.*
3. *Organization of the forest.*
   (a) The subtropical rain forest is arranged in five or six tiers or storeys.
   The top storey or very tall trees receives full sunlight and wind.
   The second storey receives full sunlight, but is protected from the full force of the wind.
   The remaining storeys are protected from the wind by the taller trees, which at the same time cut off light from the lower storeys.
   (b) The sub-antarctic rain forest forms a very close canopy over the forest floor, with the result that generally nothing but young beech trees and a few ferns grow there.

4. *History and origin of the forest.*
   (a) Whether the sub-tropical rain forest is extending into the beech forest.
   (b) Whether there is regrowth after a burn or timber milling.
   (c) Whether the character of the forest is being changed by animals such as deer, pigs, and goats.

BIBLIOGRAPHY FOR FOREST FIELD STUDY

The Trees of New Zealand . . L. Cockayne and E. Phillips Turner
The Flora of New Zealand . . . . W. Martin
A Book of Ferns . . . . . Greta Stevenson
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Plants of New Zealand . R. M. Laing and E. W. Blackwell
Useful for reference and general background.

6

Basic Chemistry

BEFORE YOU COMMENCE the study of a new section of chemistry, it is advisable that you should revise some of the basic ideas you learnt in the earlier part of the course.

ELEMENTS, MIXTURES, AND COMPOUNDS

You will recall that everything in the universe is built up from *elements* which are simple substances that have not been split up into anything simpler by ordinary chemical means.*

When two or more of these elements combine together in definite proportions, other substances called *compounds* are formed.

Both elements and compounds possess characteristic properties by which they can be recognized and below are listed some of the most important ones.

Physical properties

S State, i.e. solid, liquid or gas.
H Hardness.
A Appearance and colour.
D Density.
O Odour.
S Solubility.

Chemical properties

1. Action of heat.
2. Action of water. (Do not confuse with solubility.)
3. Action of acids and alkalis.

When elements and compounds are mixed together they may form a *mixture* in which the ingredients retain their own properties, e.g. a mixture of sand and sugar would feel gritty and taste sweet.

When two or more elements combine to form a compound, their properties are changed, e.g. sodium is a metal which reacts vigorously with water and chlorine is a poisonous gas. When they combine to form sodium chloride (NaCl) both elements acquire new sets of properties.

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*The usual chemical methods employed to decompose substances are:

1. Heat — $2HgO = 2Hg + O_2$
2. Electrolysis (see p. 79) — $2H_2O = 2H_2 + O_2$
3. Action of other elements — $ZnO + C = Zn + CO$

Here is a summary of the more important differences between elements, compounds, and mixtures.

ELEMENTS e.g. sulphur	COMPOUNDS e.g. sodium chloride	MIXTURES e.g. sugar plus sand
1. Contain only one kind of atom.	Formed when two or more different elements combine in definite proportions.	Made up of elements and/or compounds in any proportion.
2. Definite properties.	Definite properties which are quite distinct from those of the constituent elements.	Variable properties which usually resemble those of the constituents.

Elements

Approximately one hundred different elements are known. The majority of these are solids at ordinary temperatures, but a few exist as liquids or gases. Here are some examples:

Solids iron, copper, tin, zinc, lead, aluminium, sulphur, carbon, and phosphorus.
Liquids mercury and bromine.
Gases oxygen, hydrogen, nitrogen, and chlorine.

Many of the elements are common metals while others have no metallic properties whatsoever. It is customary to list the characteristic properties of these two classes, but later on you will learn that there are other elements which have properties intermediate between the two types.

METALS	NON-METALS
Physical properties	*Physical properties*
1. Characteristic metallic lustre.	No metallic lustre.
2. Malleable and ductile, i.e. can be hammered into shape and drawn out into wire.	Not malleable or ductile.
3. Good conductors of heat and electricity.	Poor conductors of heat and electricity.
4. They are all solids except mercury.	There are solid, liquid, and gaseous non-metals.
5. Most of the common metals have high densities and high melting points.	Most non-metals have low densities and low melting points.
Chemical properties	*Chemical properties*
1. Most of them react with dilute acids.	Not attacked by dilute acids.
2. They have basic oxides.	They have acidic oxides.

SOME IMPORTANT COMPOUNDS

OXIDES

Acidic oxides

1. They are formed when non-metals combine with oxygen.

$$C + O_2 = CO_2$$

2. Many combine with water to form acids.

$$SO_3 + H_2O = H_2SO_4$$

3. They react with bases to form salts.

$$2NaOH + CO_2 = Na_2CO_3 + H_2O$$

Basic oxides

1. Most metals form basic oxides.

$$2Mg + O_2 = 2MgO$$

2. Nearly all basic oxides are insoluble in water, but a few react with water to form alkalis.*

$$CaO + H_2O = Ca(OH)_2$$

3. They form salts with acids.

$$PbO + 2HNO_3 = Pb(NO_3)_2 + H_2O$$

4. They can be prepared by one or more of the following methods. Heating the—

(a) metal in air $2Mg + O_2 = 2MgO$

(b) hydroxide $Cu(OH)_2 = CuO + H_2O$

(c) carbonate $CaCO_3 = CaO + CO_2$

(d) nitrate $2Zn(NO_3)_2 = 2ZnO + 4NO_2 + O_2$

ACIDS

An acid is a compound containing hydrogen which can be replaced by metals under certain conditions.

$$H_2SO_4 + Zn = ZnSO_4 + H_2$$

1. They have a sour taste.

2. They turn blue litmus red.

3. They react with metals, metallic oxides, and hydroxides to form salts.

$$Fe + H_2SO_4 = FeSO_4 + H_2$$

$$MgO + 2HCl = MgCl_2 + H_2O$$

$$NaOH + HNO_3 = NaNO_3 + H_2O$$

*An alkali is a soluble hydroxide, e.g. sodium hydroxide.

4. They liberate carbon dioxide from carbonates.

$$Na_2CO_3 + H_2SO_4 = Na_2SO_4 + H_2O + CO_2$$

5. They corrode metals.

Bases

A base is a substance which will react with an acid to form a salt and water only.

1. The oxides and hydroxides of most metals are bases.
2. They react with acids to form salts.

$$CaO + 2HCl = CaCl_2 + H_2O$$
$$Ca(OH)_2 + 2HCl = CaCl_2 + 2H_2O$$

3. Practically all bases are insoluble in water and consequently they have no action on litmus. The principal exceptions* are sodium and potassium hydroxides, which are called alkalis. Their solutions turn red litmus blue.

Salts

A salt is a compound which is formed when all or part of the hydrogen of an acid is replaced by a metal.

Types

1. A *normal salt* is formed when the hydrogen of an acid is completely replaced by a metal.
2. An *acid salt* is a compound in which only part of the hydrogen of an acid is replaced by a metal.

Acid	*Acid salt*	*Normal salt*
H_2CO_3	$NaHCO_3$	Na_2CO_3
H_2SO_4	$KHSO_4$	K_2SO_4

Preparation

1. Soluble salts are usually prepared by the action of an acid on:
   (a) a metal $Zn + H_2SO_4 = ZnSO_4 + H_2$
   (b) a metallic oxide $CuO + 2HNO_3 = Cu(NO_3)_2 + H_2O$
   (c) a hydroxide $NaOH + HCl = NaCl + H_2O$
   (d) a carbonate $K_2CO_3 + 2HCl = 2KCl + H_2O + CO_2$
2. Insoluble salts are prepared by double decomposition (see p. 69).

$$CaCl_2 + Na_2SO_4 = 2NaCl + CaSO_4 \downarrow$$

*Calcium and magnesium hydroxides are slightly soluble in water.

SOLUBILITY OF COMMON COMPOUNDS IN WATER*

NITRATES	All soluble.
CHLORIDES	All soluble except silver chloride and lead chloride.
SULPHATES	All soluble except calcium sulphate, lead sulphate, and silver sulphate. and Barium Sod.
CARBONATES	All insoluble except the carbonates of potassium, sodium, and ammonium.
HYDROXIDES	All insoluble except the hydroxides of potassium, sodium, calcium, and ammonium.

PHYSICAL AND CHEMICAL CHANGE

Substances can undergo either physical or chemical changes, and the characteristics of each type are given below.

PHYSICAL CHANGE	CHEMICAL CHANGE
1. No new substance is formed. 2. In most cases, it is easy to reverse the change.	A new substance is always formed. Can be reversed only by carrying out further chemical changes.

Examples of physical changes

1. A change of state, e.g. ice to water to steam.
2. Many substances dissolve in liquids to form solutions.
3. Zinc oxide is normally white, but it turns yellow when heated.
4. Most substances expand on heating and contract on cooling.
5. A piece of iron can be magnetized.

Types of chemical change

1. Direct combination. Two or more elements or compounds react to form new substance.

$$Fe + S = FeS$$
$$CaO + CO_2 = CaCO_3$$

2. Decomposition. A compound is split up into two or more simpler substances.

$$2HgO = 2Hg + O_2$$
$$2KClO_3 = 2KCl + 3O_2$$

*This table refers to the compounds of potassium, sodium, ammonium, calcium, magnesium, aluminium, zinc, iron, lead, copper, and silver.

3. Replacement. One element replaces another element in its compound.

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

$$Fe + CuSO_4 = FeSO_4 + Cu$$

4. Double decomposition. Two compounds react in such a way as to exchange radicals. Usually, one of the products is either insoluble or gaseous.

$$NaCl + AgNO_3 = NaNO_3 + AgCl \downarrow$$

VALENCY

In your study of compounds, you learned that they were formed when elements combined in definite proportions. As atoms are the smallest particles that can take part in a chemical change, it is obvious that a molecule of a compound must contain a definite number of atoms of each element. Thus two atoms of hydrogen combine with one atom of oxygen to form one molecule of water, i.e. H_2O.

Now each element has a characteristic combining power or VALENCY which must be known before you can write the formula of any of its compounds. In the earlier part of the course you learned that the common metals took the place of either one of two hydrogen atoms. Now you must extend your knowledge a little further and learn that *the valency of an element is the number of hydrogen atoms or their equivalent which will combine with or replace one atom of the element.*

HCl	Chlorine has a valency of 1
H_2O	Oxygen has a valency of 2
NH_3	Nitrogen has a valency of 3
CH_4	Carbon has a valency of 4

Radicals are groups of atoms which occur in related compounds, e.g. all sulphates contain the sulphate radical SO_4, e.g. H_2SO_4, Na_2SO_4, $CaSO_4$.

The nitrate radical NO_3 has a valency of 1, e.g. HNO_3

The carbonate radical CO_3 has a valency of 2, e.g. H_2CO_3

The phosphate radical PO_4 has a valency of 3, e.g. H_3PO_4

Here is a table showing the valencies of the elements and radicals you should know:

Valencies of Common Elements and Radicals

METALS AND POSITIVE RADICALS

VALENCY 1		VALENCY 2		VALENCY 3	
Hydrogen	H	Calcium	Ca	Aluminium	Al
Potassium	K	Magnesium	Mg	Iron (ferric compounds)	Fe
Sodium	Na	Zinc	Zn		
Silver	Ag	Iron (ferrous compounds)	Fe		
Ammonium	NH_4	Lead	Pb		
		Copper	Cu		

NON-METALS AND NEGATIVE RADICALS

VALENCY 1		VALENCY 2		VALENCY 3	
Hydroxide	OH	Oxide	O	Nitride	N
Nitrate	NO_3	Sulphide	S	Phosphate	PO_4
Chloride	Cl	Sulphate	SO_4		
Chlorate	ClO_3	Carbonate	CO_3		

Formulae

In every compound, each element must satisfy its combining power. Thus carbon, which has a valency of 4, will combine with four univalent atoms, as in CCl_4, or with two divalent atoms, as in CO_2.

When the number of atoms required is not a whole number, you can use the following method to determine the formulae of simple compounds:

1. Calculate the L.C.M. of the two valencies.
2. Divide the valency of each atom or radical into the L.C.M. in order to determine the number of atoms or groups required.

Aluminium oxide

ELEMENT	VALENCY	L.C.M.	NO. OF ATOMS
Al	3	6	2
O	2		3

Formula is Al_2O_3

Calcium phosphate

ELEMENT OR RADICAL	VALENCY	L.C.M.	NO. OF ATOMS OR RADICALS
Ca	2	6	3
PO_4	3		2

Formula is $Ca_3(PO_4)_2$

EQUATIONS

1. Write down the names of the reagents used and the products formed.

   Zinc + hydrochloric acid = zinc chloride + hydrogen

2. Now write the formula of each substance.

   $$Zn + HCl \rightarrow ZnCl_2 + H_2$$

3. Check the number of atoms of each element on both sides of the equation and increase the number of molecules until the equation balances.

   $$Zn + 2HCl = ZnCl_2 + H_2$$

CHEMICAL ARITHMETIC

ATOMIC WEIGHTS

Although atoms are so extremely small that they cannot be seen even with the most powerful microscope, it is possible to determine the weights of individual atoms of any element, e.g. one atom of hydrogen weighs 0·000,000,000,000,000,000,000,0017 grams.

As you can see, this is a very awkward number, so chemists decided to use a simpler one, which is really a modified relative density. As hydrogen has the lightest atom, they took hydrogen as the unit and calculated how many times the atoms of the other elements were heavier, e.g. one atom of nitrogen is 14 times as heavy as one atom of hydrogen, so that we say nitrogen has an atomic weight of 14. Here are the approximate atomic weights of some of the common elements:

Hydrogen	1	*Magnesium*	24·5	*Potassium*	39
Carbon	12	*Aluminium*	27	*Calcium*	40
Nitrogen	14	*Phosphorus*	31	*Iron*	56
Oxygen	16	*Sulphur*	32	*Copper*	63·5
Sodium	23	*Chlorine*	35·5	*Zinc*	65·5
				Lead	207

Molecular Weights

When elements combine to form compounds, it will be seen that the relative weight of one molecule of it will be equal to the sum of the atomic weights.

FORMULA	ATOMIC WEIGHTS	MOLECULAR WEIGHT
CaO	$40 + 16$	56
H_2O	$(1 \times 2) + 16$	18
SO_2	$32 + (16 \times 2)$	64
Al_2O_3	$(27 \times 2) + (16 \times 3)$	102

To Determine the Percentage Weight of Each Element in a Compound

$$\underbrace{CaCO_3}_{40 + 12 + (16 \times 3)}$$

Molecular weight $= 100$

In every 100 parts by weight of calcium carbonate, there will be 40 parts of calcium, 12 parts of carbon, and 48 parts of oxygen. Most compounds do not work out as simply as this, but the principle is just the same.

EXAMPLE *Determine the percentage weight of each element in sodium sulphate.*

$$\underbrace{Na_2SO_4}_{(23 \times 2) + 32 + (16 \times 4)}$$

Molecular weight $= 142$

Sodium $\quad \frac{46}{142} \times \frac{100}{1} = 32{\cdot}4$ per cent

Sulphur $\quad \frac{32}{142} \times \frac{100}{1} = 22{\cdot}5$ per cent

Oxygen $\quad \frac{64}{142} \times \frac{100}{1} = 45{\cdot}1$ per cent

Calculations from Equations

When an equation is properly balanced it can be used to determine the weights of both the substances taking part and the products formed in the reaction. By this means a manufacturer is able to calculate the correct weights of each substance he will have to use in order to prepare a particular quantity of his product.

$CaCO_3$	=	CaO	+	CO_2
$40 + 12 + 48$		$40 + 16$		$12 + 32$
100 units of weight		56 units of weight		44 units of weight

If he wanted to prepare 56 units of weight of calcium oxide, he would have to heat 100 units of weight of calcium carbonate. As atomic and molecular weights are relative, he can use any units of weight he chooses:

$CaCO_3$	=	CaO	+	CO_2
100 pounds / tons / grams / etc.	=	56 pounds / tons / grams / etc.	+	44 pounds / tons / grams / etc.

Here are two examples that will show you how to set out your calculation:

1. What weight of sulphur dioxide will be formed when 4 lb of sulphur is burnt in air?

(a) Write the equation and balance it.

$$S + O_2 = SO_2$$

(b) Determine the atomic and molecular weights of the substances mentioned.

$$\underset{32}{S} + O_2 = \underset{64}{SO_2}$$

(c) Calculate the required weight by simple proportion.
Note. Write down what you are required to find at the beginning of your statement.

Wt. of sulphur dioxide obtained from 32 lb of S = 64 lb

" " " " 4 " " $= \frac{64}{1} \times \frac{4}{32}$ lb

$= 8$ lb

2. What weight of iron must be placed in excess sulphuric acid in order to prepare 19 cwt of iron sulphate?

(a) $Fe + H_2SO_4 = FeSO_4 + H_2$

(b) $\underset{56}{Fe} \qquad \underbrace{56 + 32 + 64}_{152}$

(c) *Wt. of iron* required to yield 152 cwt of $FeSO_4$ = 56 cwt

" " " 19 " " $= \frac{56}{1} \times \frac{19}{152}$ cwt

$= 7$ cwt

EXERCISE

A. State the type of chemical change that takes place in each of the following reactions:

1. $Na_2CO_3 + CaCl_2 = 2NaCl + CaCO_3$.
2. $C + H_2O = CO + H_2$.
3. $NH_3 + HCl = NH_4Cl$.
4. $Zn + CuSO_4 = ZnSO_4 + Cu$.
5. $P_2O_5 + H_2O = 2HPO_3$.
6. $Cu + N_2O = CuO + N_2$.
7. $CaCO_3 + H_2CO_3 = Ca(HCO_3)_2$.
8. $2PbO_2 = 2PbO + O_2$.
9. $Cl_2 + 2KI = 2KCl + I_2$.
10. $6PbO + O_2 = 2Pb_3O_4$.

B. Write the formulae of the following compounds:

1. Calcium nitrate.
2. Sodium hydroxide.
3. Copper chloride.
4. Ammonium sulphate.
5. Sodium sulphate.
6. Ferric oxide.
7. Potassium phosphate.
8. Zinc hydroxide.
9. Ferrous nitrate.
10. Ferric sulphate.

C. Calculate the molecular weights of the following compounds:

1. MgO
2. SO_3
3. Al_2O_3
4. NaOH
5. NH_4Cl
6. K_2CO_3
7. $Ca(OH)_2$
8. Pb_3O_4
9. $C_6H_{10}O_5$
10. $Ca(HCO_3)_2$

D. Calculate the percentage weight of each element in the compounds given in '*C*'.

E. 1. What weight of limestone must be heated to yield 14 lb of burnt lime?

2. What weight of calcium hydroxide would be formed when 7 grams of calcium oxide are slaked with water?

3. What weight of calcium carbonate would be precipitated when excess sodium carbonate is added to a solution containing 55·5 grams of calcium chloride?

4. What weight of ferrous sulphate would be formed when 8 cwt of iron react with sulphuric acid?

5. Calculate the weight of potassium chlorate which must be heated to yield 12 grams of oxygen.

REVISION TEST

1. Are the following substances metals or non-metals?
   (*a*) Sodium. M
   (*b*) Carbon. NM
   (*c*) Calcium. M
   (*d*) Magnesium. M
   (*e*) Phosphorus. NM

2. Are the following changes physical or chemical?
   (*a*) Burn coal. C
   (*b*) Melt wax. P
   (*c*) Dissolve zinc in sulphuric acid. C
   (*d*) Dissolve common salt in water. P
   (*e*) Magnetize a piece of iron. P

3. Are the following substances acids, bases, or salts?
   (*a*) CuO B
   (*b*) $FeCl_2$ S
   (*c*) H_2SO_4 A
   (*d*) $Ca(OH)_2$ B
   (*e*) $PbCO_3$ S

4. Are the following substances elements, mixtures, or compounds?
   (*a*) Milk. M
   (*b*) Sulphur. E
   (*c*) Sodium carbonate. C
   (*d*) Copper. E
   (*e*) Solder. M

5. Are these oxides acidic, basic, or neutral?
   (*a*) Copper oxide. B.
   (*b*) Water. N
   (*c*) Sulphur dioxide. A
   (*d*) Phosphorus pentoxide. A
   (*e*) Sodium oxide. B.

6. Write the formulae of the following compounds:
   (*a*) Zinc nitrate. $Zn(NO_3)_2$
   (*b*) Magnesium hydroxide. $Mg(OH)_2$
   (*c*) Iron sulphate. FeS
   (*d*) Ammonium carbonate. $(NH_4)_2CO_3$.
   (*e*) Carbonic acid. H_2CO_3

7. Name the salt formed when:
   (*a*) Sulphuric acid reacts with magnesium. Mg. Sulphate.
   (*b*) Hydrochloric acid acts on zinc carbonate. Zn. Chloride.
   (*c*) Nitric acid is added to sodium hydroxide. Na. Nitrate.
   (*d*) Carbon dioxide is passed over calcium oxide. Ca. Carbonate.
   (*e*) Nitric acid is added to lead oxide. Pb ~~Nitrate~~.

8. State whether the following reactions are examples of combination, decomposition, double decomposition, or replacement:
   (*a*) $2Pb(NO_3)_2 = 2PbO + 4NO_2 + O_2$. decomp.
   (*b*) $Fe + S = FeS$. Combination
   (*c*) $CuSO_4 + 2NaOH = Cu(OH)_2 + Na_2SO_4$. Double. decomp.
   (*d*) $Zn + H_2SO_4 = ZnSO_4 + H_2$. Replacement
   (*e*) $NH_3 + HCl = NH_4Cl$. Combination.

9. What number must be written in place of x to make the equations balance?

(*a*) $SO_2 + 2H_2S = 2H_2O + xS$.

(*b*) $4NH_3 + xO_2 = 4NO + 6H_2O$.

(*c*) $2CuSO_4 + xKI = 2K_2SO_4 + 2CuI + I_2$.

(*d*) $3Cu + xHNO_3 = 3Cu(NO_3)_2 + 4H_2O + 2NO$.

(*e*) $FeCl_3 + xH_2O = Fe(OH)_3 + 3HCl$.

10. What is the valency of?

(*a*) Copper in CuO.

(*b*) Sodium in NaCl.

(*c*) Nitrogen in NH_3.

(*d*) Sulphate radical in H_2SO_4.

(*e*) Oxygen in H_2O.

11. Name the substance formed when water reacts with:

(*a*) Carbon dioxide.

(*b*) Sodium oxide.

(*c*) Phosphorus pentoxide.

(*d*) Sulphur trioxide.

(*e*) Calcium oxide.

12. Name four substances which yield zinc oxide when they are heated.

7

Hydrogen

EXPERIMENT *To study the action of metals on water.*

Your teacher will drop a piece of sodium* about the size of a BB shot into a beaker of water. Note particularly the following points:

(a) Although sodium is a metal, it floats on water.

(b) Observe that a gas is evolved and test it with a lighted taper.

(c) After the reaction is complete, test the liquid in the beaker with litmus paper. What type of compound is present?

(d) Rub the liquid between your thumb and forefinger and note the soapy feel.

Another very reactive metal is calcium. Drop small pieces of it into a beaker of water and make these tests:

(a) Invert a small test-tube of water over the calcium and collect some of the gas that is evolved. Place your thumb over the mouth of the test-tube and then allow the gas to escape near a bunsen flame. What do you observe?

(b) Test the liquid in the beaker with pieces of litmus paper. What type of compound is present?

None of the common metals reacts with cold water to produce a gas, but some of them will do so if they are heated. Here are two examples:

1. Place some magnesium ribbon or powder in a test-tube half filled with water and add one drop of phenolphthalein.† If you heat the water until it is nearly boiling you should be able to see small bubbles of gas being liberated, but the amount will be too small for you to collect and test. However, the liquid will change colour and you should be able to explain the chemical reaction that has taken place.

2. Fit up the apparatus shown in *Figure 25* and fill the two-foot length of half-inch iron water pipe with small iron nails. When the pipe has been heated to red heat, pass a current of steam through it until all the air has

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**AS SODIUM IS SUCH A REACTIVE SUBSTANCE, PUPILS MUST NOT DO ANY EXPERIMENTS WITH IT THEMSELVES. IT HAS CAUSED SEVERAL SERIOUS EXPLOSIONS IN THE PAST. NOTE THAT IT IS STORED UNDER KEROSENE.*

†Phenolphthalein is an indicator. It is colourless in acid solution but turns red in the presence of alkalis.

been swept out and then collect the gas in a test-tube. When the test-tube is full, remove it from the trough and apply a lighted taper. Does the gas resemble that given off in the previous experiments?

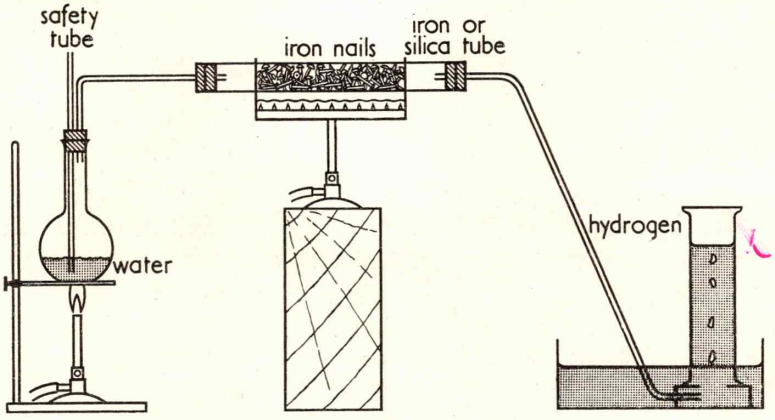


FIG. 25. Action of steam on red-hot iron.

The gas given off in these experiments is hydrogen and the equations for the reactions are:

Sodium	$2Na + 2H_2O = 2NaOH + H_2$
Calcium	$Ca + 2H_2O = Ca(OH)_2 + H_2$
Magnesium	$Mg + 2H_2O = Mg(OH)_2 + H_2$
Iron	$3Fe + 4H_2O = Fe_3O_4 + 4H_2$

As you observed, some metals react more vigorously than others. Chemists have used this and other reactions to arrange them in the following order:

Sodium	reacts with cold water.
Calcium	,, ,, cold water.
Magnesium	,, ,, boiling water.
Aluminium	,, ,, steam.
Zinc	,, ,, steam.
Iron	,, ,, steam.
Lead	,, ,, steam.
Copper	does not react at any temperature.
Silver	does not react at any temperature.
Gold	does not react at any temperature.

EXERCISE Write the equations for each of the above reactions.

If a metal reacts with water, it forms the hydroxide, e.g. NaOH and $Ca(OH)_2$, but those that have to be heated in steam yield the oxide, e.g. Al_2O_3, ZnO, Fe_3O_4, and PbO.

In the course of your work in Chemistry, you will find this arrangement of the metals (it is called the Replacement Series) a very useful guide. So far you have learned:

1. Metals high up in the series react more vigorously than those further down.
2. Only the metals before copper liberate hydrogen from water.

Later on we shall study the action of acids on these metals and compare the results with those you obtained with water.

Decomposition of Water

So far you have discovered that water is a compound that probably consists of the two elements hydrogen and oxygen because:

1. Some metals liberate hydrogen from it.
2. When some metals are heated in steam, they form oxides, e.g. iron oxide.

The next step is to verify this by decomposing water into its elements. When it is heated, the only thing that happens is that it changes into steam. As heat does not decompose water, we must use a more powerful agent to split it up into its elements, viz. an electric current.

Electrolysis of Water

As pure water does not conduct an electric current very readily, we have to add to it some acid or alkali. These substances improve the conductivity and enable the reaction to proceed, but are not changed chemically in the process. If necessary, they could be recovered completely at the end of the experiment.

EXPERIMENT *To determine what happens when an electric current is passed through water.*

The apparatus used is called a voltameter. Fill it with water to which has been added a little sulphuric acid or sodium hydroxide. Now connect the electrodes to a 12-volt or 24-volt battery and leave for a short time.

1. Measure the volume of gas in each tube.
2. To which terminal of the battery is connected the tube containing the larger volume of gas?
3. Release this gas into a small test-tube held mouth downwards over the jet. Close the mouth of the test-tube with your thumb and then liberate the gas near a bunsen flame. Explain what happens.

4. Open the tap of the tube containing the smaller quantity of gas and hold a glowing splint above it. Explain what happens.

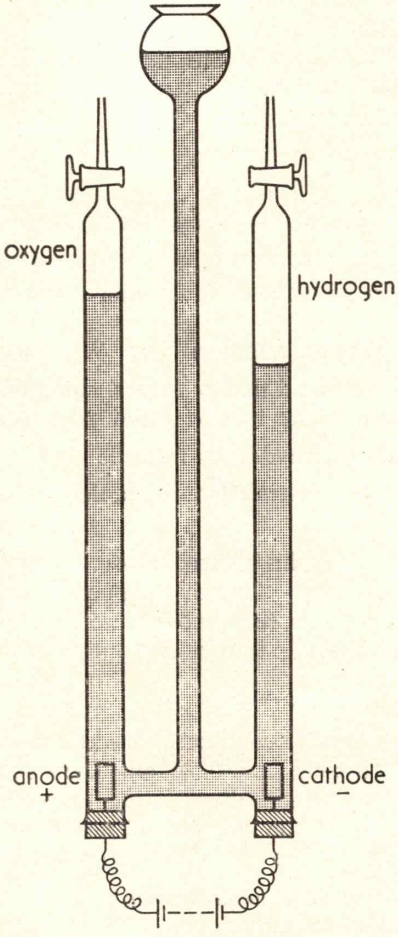


FIG. 26. The electrolysis of water.

SUMMARY

When an electric current is passed through water, the water is decomposed into two volumes of hydrogen and one volume of oxygen. The hydrogen is given off at the electrode connected to the negative terminal (cathode) and the oxygen at the positive electrode (anode).

$$2H_2O = 2H_2 + O_2$$

OXIDATION AND REDUCTION

EXPERIMENT *To study oxidation.*

1. Heat samples of different elements in air, and note the appearance of the substances that are formed. Magnesium ribbon, sulphur, red phosphorus, iron wire, and copper foil are suitable.

2. Fill a gas jar with hydrogen sulphide* and then apply a lighted taper. What is the deposit that forms on the sides of the jar?

In the first set of experiments the elements combined with the oxygen of the air to form oxides.

In the next experiment, when you burned the compound hydrogen sulphide, a deposit of yellow sulphur was left. Here is the equation for the reaction.

$$2H_2S + O_2 = 2H_2O + S$$

The oxygen did not combine with the hydrogen sulphide as it did with the elements—it simply removed the hydrogen and left sulphur. Both are examples of *oxidation*, which is defined as *the addition of oxygen or the removal of hydrogen from a substance.*

$2Mg + O_2 = 2MgO$	Mg	is oxidized	to	MgO
$S + O_2 = SO_2$	S	,,	,,	SO_2
$4P + 5O_2 = 2P_2O_5$	P	,,	,,	P_2O_5
$3Fe + 2O_2 = Fe_3O_4$	Fe	,,	,,	Fe_3O_4
$2Cu + O_2 = 2CuO$	Cu	,,	,,	CuO
$2H_2S + O_2 = 2H_2O + S$	H_2S	,,	,,	S

The reverse process, viz. *the removal of oxygen or the addition of hydrogen to a substance*, is called *reduction.* Here are three experiments to illustrate this type of reaction.

EXPERIMENT *To study reduction.*

1. Place a little litharge in a small hole scooped out in a carbon block and heat it with a mouth blowpipe. Very soon, small globules of molten lead will appear.

$$PbO + C = Pb + CO$$

Reduction is an extremely important industrial process, as it is the method by which some of our metals are obtained from their ores, e.g. iron is produced by heating iron ore with coke in a blast furnace (see page 89).

$$Fe_2O_3 + 3C = 2Fe + 3CO$$

---

*Place a small piece of iron sulphide in a gas jar and cover it with bench sulphuric acid. If left for a few minutes the jar will be filled with hydrogen sulphide,

$$FeS + H_2SO_4 = FeSO_4 + H_2S$$

2. Connect up the apparatus shown in *Figure 27* and place in the combustion tube some black copper oxide, and in the first U-tube a few lumps of calcium chloride. As this substance has a powerful affinity for water it is used to dry the gas before it enters the combustion tube.

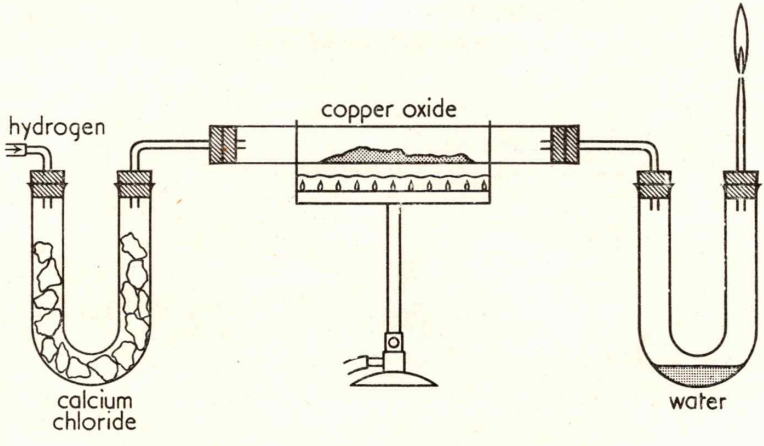


FIG. 27. Reduction of copper oxide.

The reducing agent to be used in this experiment is hydrogen, which could be generated by the action of zinc on hydrochloric acid but it is more convenient to use coal gas (if it is available), as this contains fifty per cent of hydrogen. Whether you use coal gas or hydrogen, the following precaution must be observed. Attach a length of rubber tubing to the jet, and after the gas has been passing through the apparatus for a few minutes collect a sample of it in a test-tube inverted over water. If the gas in the test-tube burns quietly it is safe to proceed. If it pops loudly, test further samples until a satisfactory result is obtained. While these tests are being carried out, keep all naked flames away from the apparatus.

Now light the jet, and also the bunsen under the combustion tube, and leave for ten minutes. Allow to cool and shake out the contents of the combustion tube into an evaporating dish. You will observe that the black copper oxide has turned reddish brown, indicating the presence of copper. The liquid which has condensed in the U-tube was not present in the original gas, which was dried by passing it through calcium chloride. Consequently, it must have been formed during the reaction. You can demonstrate that it is water, as it will turn anhydrous copper sulphate blue. Here is the equation for the reaction:

$$CuO + H_2 = Cu + H_2O$$

As you see, the copper oxide has been reduced to copper, i.e. the oxygen has been removed.

3. Place some iron sulphide and dilute hydrochloric acid in a test-tube fitted with a cork and delivery tube, and bubble the gas evolved (hydrogen sulphide) into chlorine or bromine water. The creamish white precipitate which is formed is sulphur.

If you study the equation for the reaction

$$H_2S + Cl_2 = 2HCl + S$$

you will see that the chlorine has combined with hydrogen, i.e. the chlorine has been reduced to hydrochloric acid.

Now look at the equation for the combustion of oxygen,

$$2H_2 + O_2 = 2H_2O$$

As the oxygen has combined with hydrogen, we can say the oxygen has been reduced.

Both of these reactions illustrate a very important relationship. In the first one,

H_2S is oxidized to S (removal of hydrogen) and

Cl_2 is reduced to HCl (addition of hydrogen).

Similarly, in the second reaction,

H_2 is oxidized to H_2O (addition of oxygen), and

O_2 is reduced to H_2O (addition of hydrogen).

Thus you will see that oxidation and reduction are complementary and must occur at the same time. If one substance is oxidized, another reagent in the reaction must be reduced.

Oxidizing agents are substances which:

1. Can supply oxygen, e.g. air, nitric acid, hydrogen peroxide.
2. Have a powerful affinity for hydrogen, e.g. chlorine.

Similarly, reducing agents are those which:

1. Combine readily with oxygen, e.g. hydrogen, carbon.
2. Can supply hydrogen, e.g. hydrogen, hydrogen sulphide.

EXERCISE

State whether the substances in italics in the following equations are oxidized or reduced, and name the product in each case.

Example: $C + H_2O = CO + H_2$ C is oxidized to CO

1. $2SO_2 + O_2 = 2SO_3$
2. $ZnO + C = Zn + CO$

3. $3Fe + 4H_2O = Fe_3O_4 + 4H_2$
4. $S + 2KNO_3 = 2KNO_2 + SO_2$
5. $PbO + CO = Pb + CO_2$
6. $Cl_2 + H_2 = 2HCl$
7. $H_2S + Cl_2 = 2HCl + S$
8. $Cl_2 + H_2S = 2HCl + S$
9. $C + 2H_2SO_4 = CO_2 + 2H_2O + 2SO_2$
10. $H_2S + 2HNO_3 = S + 2NO_2 + 2H_2O$

REVISION NOTES

HYDROGEN

OCCURRENCE

Free

Coal gas contains approximately fifty per cent of hydrogen.

Combined

1. Water.
2. All acids and alkalis.
3. Carbohydrates, e.g. sugar.
4. Hydrocarbons, e.g. petrol.

PREPARATION

Commercial

1. Electrolysis of water.
2. Pass steam over red-hot iron or carbon.

$$3\,Fe + 4H_2O = Fe_3O_4 + 4H_2$$
$$C + H_2O = CO + H_2$$

Laboratory

1. By the action of zinc on dilute hydrochloric or sulphuric acids.

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

PROPERTIES

1. Colourless, odourless gas.
2. Lightest substance known.
3. Only slightly soluble in water.
4. Burns in air with a blue flame.
5. Neutral.

REACTIONS

1. Burns in air (oxygen) to form water.

$$2H_2 + O_2 = 2H_2O$$

2. Reduces some metallic oxides to the metals.

$$CuO + H_2 = Cu + H_2O$$

USES

1. Fuel.
2. Oxy-hydrogen torch for cutting and welding metals.
3. Hydrogenation of animal and vegetable oils (margarine).
4. Hydrogenation of coal (petrol).
5. Manufacture of ammonia.
6. For filling balloons.

WATER

OCCURRENCE

It is the most abundant of all naturally-occurring compounds.

1. *Gas.* Water vapour in the air.
2. *Liquid.* Seas, rivers, lakes, etc.
3. *Solid.* Snow, ice (glaciers, icebergs, etc.).
4. It is a constituent of all living matter.

FORMATION

1. Combustion of hydrogen and hydrocarbons, e.g. petroleum.
2. By the action of an acid on metallic oxides, hydroxides, and carbonates.
3. Reduction of metallic oxides with hydrogen.

PROPERTIES

1. Colourless, odourless, tasteless liquid.
2. Density. 1g/cc, F.P. 0°C, B.P. 100°C.
3. The most valuable solvent we possess.
4. Neither burns nor supports combustion.
5. Neutral.

REACTIONS

1. The metals before copper will liberate hydrogen from water.
   (a) Sodium and calcium react with cold water.

$$Ca + 2H_2O = Ca(OH)_2 + H_2$$

(b) The other metals before copper must be heated in steam.

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2$$

2. Combines with some metallic oxides to form hydroxides.

$$CaO + H_2O = Ca(OH)_2$$

3. Combines with most non-metallic oxides to form acids.

$$SO_3 + H_2O = H_2SO_4$$

4. Water is decomposed by an electric current.

$$2H_2O = 2H_2 + O_2$$

5. Reacts with some non-metals.

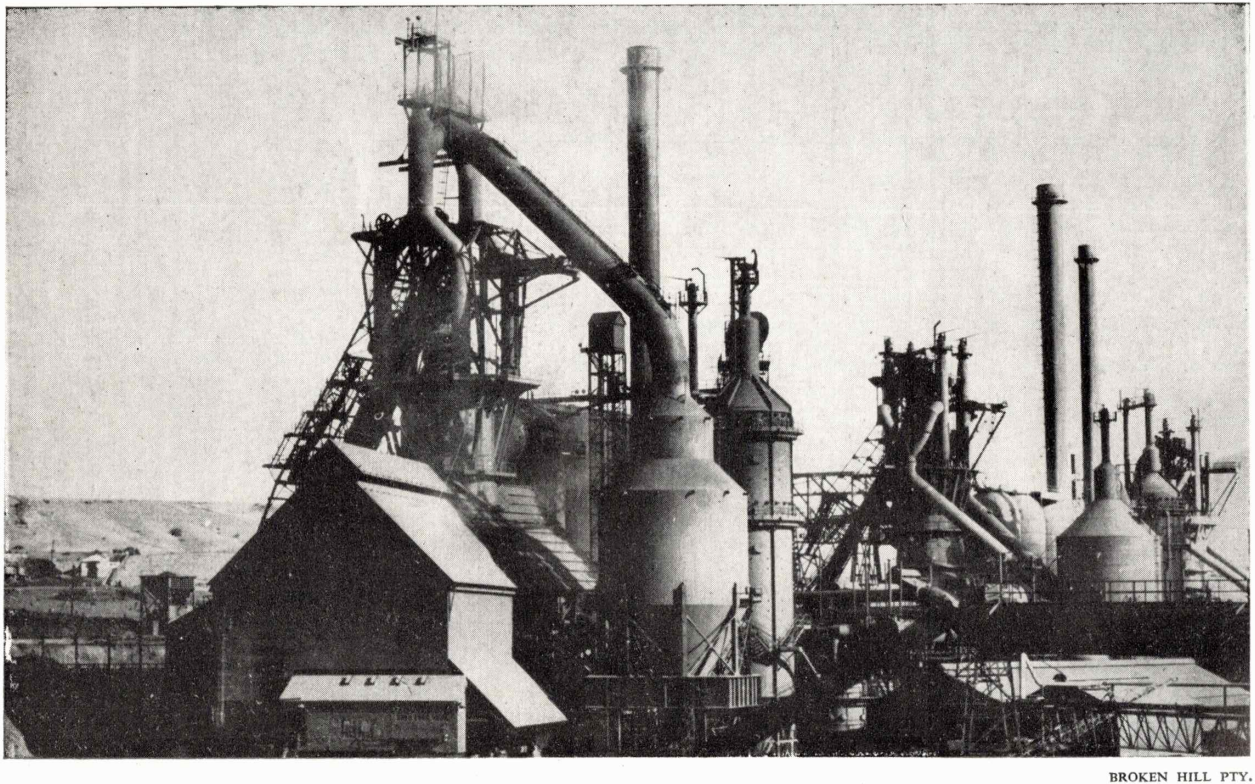
$$C + H_2O = CO + H_2$$

TESTS

1. Physical properties, e.g. density, B.P., etc.
2. Gives a blue colour with anhydrous copper sulphate.

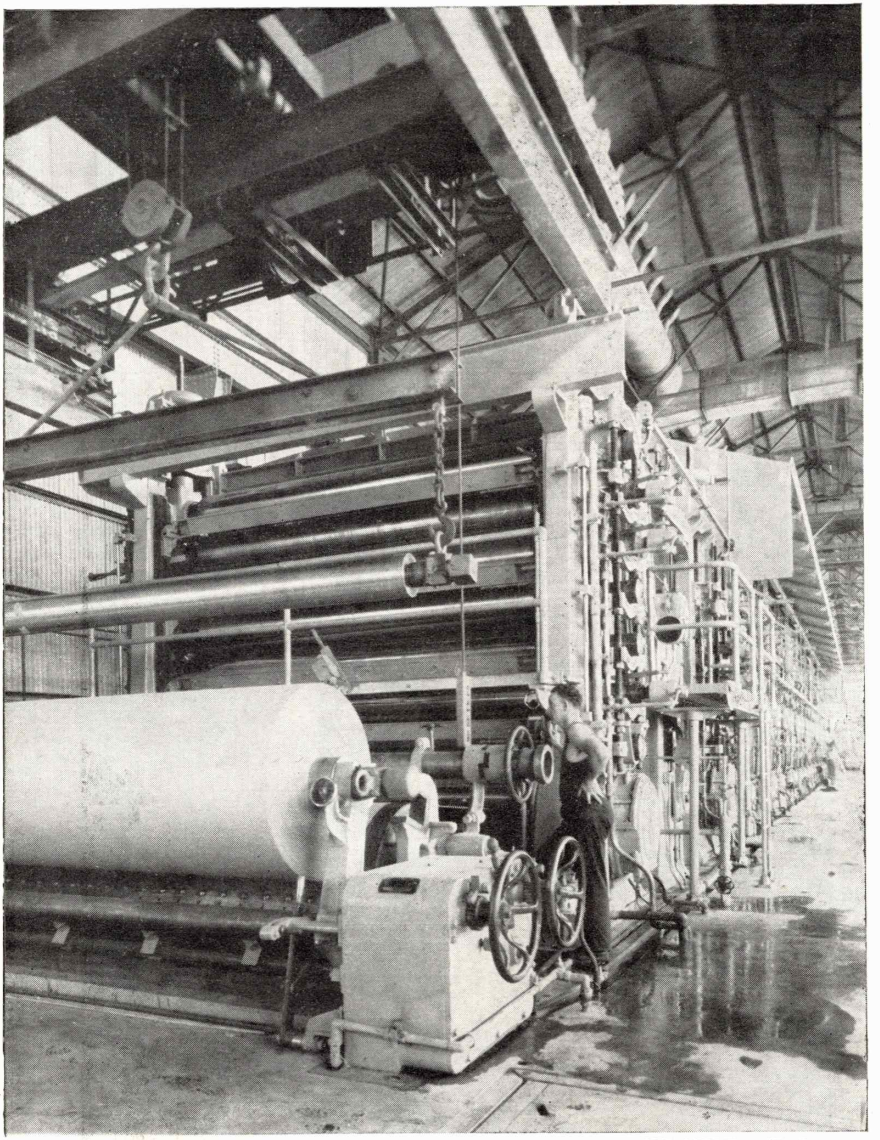
USES

1. Solvent. Food is carried to all parts of the body, and waste is removed from the body in solution. Plants absorb mineral matter dissolved in soil water.
2. Regulation of body temperature.
3. Production of power, e.g. steam engines, hydro-electric generators, etc.
4. Heating and cooling agent, e.g. central heating, cooling system on cars, ice, etc.
5. Definition of many scientific units.
6. It is the medium in which most of our chemical reactions take place.



BROKEN HILL PTY.

3. Blast furnace at Port Kembla Steel Works (Page 90)



N.Z. FOREST PRODUCTS LTD.

4. A paper-making machine (Page 107)

8

Metals

PRIMITIVE MAN was compelled to make his tools and weapons from materials found naturally in his environment, viz. wood, stones, flint, and bone, but once he was able to use fire to extract metals from the earth, great advances were possible. Some copper was found native, but it was too soft for most purposes. Tin also was easily obtained by heating tinstone with charcoal, and when man mixed these two metals he obtained bronze which was hard and tough enough for a great variety of purposes.

Since then, we have entered the iron and steel age, and at the present time Britain is producing more than a million tons of this metal a month. Now the extent to which a metal can be used depends upon:

1. Its abundance in the earth's crust.
2. The ease with which it can be extracted from its ores.
3. Its resistance to the action of air and water.

Iron satisfies the first two conditions, and although it readily rusts in air it can be protected by a layer of paint or another metal.

Aluminium, on the other hand, is nearly twice as abundant as iron, is resistant to corrosion, is only one third of the weight of iron, and can be made nearly as strong as steel; but it suffers from the severe handicap that there is no simple or cheap method of extracting it from its most abundant ores. If the price could be reduced to be comparable with that of steel, there is no doubt that aluminium would replace iron for many of the purposes for which it is used today. We have had a stone age, a bronze age, an iron age, and as soon as our chemists can devise a cheap method of extracting the metal, we shall have an aluminium age.

HOW METALS OCCUR IN NATURE

When iron is left exposed to air and moisture it is slowly converted into a brown powdery substance called rust. If there was any iron in the earth's crust, it would soon be changed into rust by the action of oxygen and moisture which occur in the soil. Huge beds of iron ore

are found in many countries, and occasionally when these deposits are eroded by the action of water the ore appears again as iron sand, huge quantities of which are found on the Taranaki and other west coast beaches. So far, no practical method has been devised to obtain iron from iron sand.* The only other large deposit of iron ore in New Zealand is at Parapara on Golden Bay, and a small blast furnace has been working intermittently at Onekaka since 1924. As an iron and steel mill cannot be operated economically on a small scale, it would appear that we shall be dependent upon Australia and England for practically all future supplies of this metal.

Only those metals which are not readily corroded by air and water, e.g. gold, platinum, occur naturally. All other metals resemble iron in that they are normally found in the form of compounds called ores.

The following are the most important naturally-occurring compounds of the metals you are studying.

Sodium	The chloride (NaCl), nitrate ($NaNO_3$), and complex salts.
Calcium	The carbonate ($CaCO_3$), sulphate ($CaSO_4$), and complex salts.
Magnesium	The carbonate ($MgCO_3$), sulphate ($MgSO_4$), and chloride ($MgCl_2$).
Aluminium	The oxide (Al_2O_3) and silicates.
Zinc	The sulphide (ZnS) and carbonate ($ZnCO_3$).
Iron	The oxides (Fe_2O_3 and Fe_3O_4) and sulphide (FeS_2).
Lead	The sulphide (PbS).
Copper	The sulphide ($CuFeS_2$).

New Zealand has a very wide range of minerals, but in very few cases are the deposits sufficiently large to warrant the erection of plants to extract them.

How Metals are Extracted from their Ores

EXPERIMENT *Reduction of litharge.*

Revise this experiment, which was described on page 81. This method is used industrially for extracting a number of metals, e.g. zinc, tin, and iron, and as iron is our most important metal, a brief description will be given of the process.

*As our ironsands contain appreciable quantities of titanium, possible methods of extracting this element are being investigated. Its oxide (TiO_2) is a very important white pigment used in paints. It may be possible to extract iron from the residue.

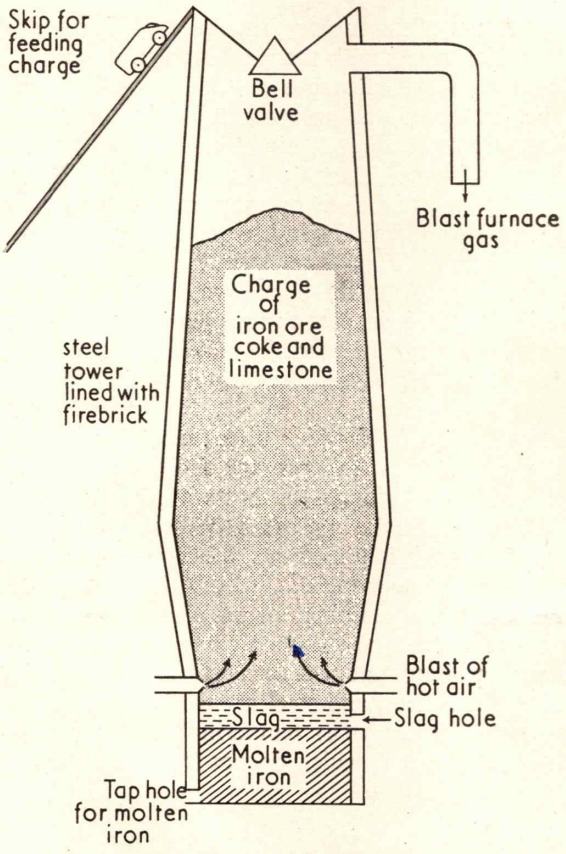


FIG. 28. A blast furnace.

EXTRACTION OF IRON

Iron ore, which is an oxide of the metal (Fe_2O_3 or Fe_3O_4) is mixed with coke and limestone and fed into the top of a blast furnace, which is simply a steel tower lined with fire brick. When a blast of hot air is forced in at the bottom, the coke burns, producing a temperature of 1200-1400°C, and at the same time it reacts with some of the iron ore, reducing it to iron, which runs down and collects in the bottom of the furnace.

$$Fe_2O_3 + 3C = 2Fe + 3CO$$

The carbon monoxide which has been formed reduces more of the iron.

$$Fe_2O_3 + 3CO = 2Fe + 3CO_2$$

At the temperature of the furnace, the limestone is decomposed into burnt lime, which reacts with the sand always present in the ore to form a liquid glass-like substance called slag, which gradually sinks down to the bottom of the furnace and finally floats on the surface of the molten iron. (See *Fig. 28* and *Plate 3.*)

Every four or five hours the furnace is 'tapped'. This consists of draining off the slag and then running the molten iron either into sand moulds, where it forms 'pigs', or into a crucible in which it is taken to the steel mill.

The iron obtained from the blast furnace is always very impure, and as it contains three per cent to four per cent of carbon, it is very brittle, so that it cannot be used for making articles which have to stand up to shock. However, it is quite suitable for making coal stoves, engine blocks, etc.

Steel is simply iron from which undesirable impurities have been removed. In the simplest process, the molten iron is run into an egg-shaped converter through the bottom of which a blast of air is blown. This burns off the impurities (carbon, sulphur, and silicon), and then, just before it is tipped out, other metals may be added to impart certain desirable properties. (See 'Alloys', page 92.)

When iron or steel containing one per cent to two per cent of carbon is heated to red heat and suddenly quenched in water or oil, the iron becomes very hard, and was formerly used for making the tools with which ordinary iron and steel are worked, e.g. files and drills. The process, which is known as 'tempering', has been partly replaced by the use of alloy steels, which do not lose their hardness even at red heat.

METALS IN COMMON USE

Types of Iron and Steel

Cast Iron contains 95 per cent iron, 3·5 per cent to 4·3 per cent of carbon, and some sulphur and silicon. It is very hard and brittle, and cannot withstand sudden blows, shocks, or bending. As it expands on cooling, it makes good castings. It is used for engine blocks, bases for machinery, stoves, etc.

Wrought Iron, which is the purest form of commercial iron, is made in a puddling furnace, and finally hammered to produce a fibrous structure which makes it very tough. It is used for making articles subject to sudden shock. As it is very expensive to produce, it has been largely replaced by mild steel.

Mild Steel contains a small amount of carbon, and is fine-grained and tough. It can be rolled and drawn into wire and is used in the manufacture of structural steel, galvanized iron, tinplate, utensils, wire, etc.

Steel contains up to two per cent of carbon and can be made very hard by tempering. It is used for cutlery, etc.

Other Commercial Metals

Magnesium. It is a soft metal which is usually alloyed with aluminium. As it burns brilliantly in air, it was used during the last war for flares and incendiary bombs.

Aluminium. As it is light, strong, and resistant to corrosion, it is gradually replacing steel for many structural purposes. It is used principally for aeroplane construction, roofing, kitchen utensils, etc. Also, weight for weight it is a much better conductor of electricity than copper and is being used for high tension transmission lines as the pylons can be placed further apart. Aluminium powder, when made into a paint, is used as a priming coat for both wood and metal. 'Thermite' is a mixture of aluminium powder and iron oxide. It is used for welding as it produces both a very high temperature and molten iron which fills in the crack. Lengths of tram rails can be joined together with its aid.

$$Fe_2O_3 + 2Al = Al_2O_3 + 2Fe$$

Zinc. It readily oxidizes in air, but the layer of oxide protects the metal from further corrosion so that it does not require to be painted. Steel dipped in molten zinc is called galvanized iron, which is used for roofing, window frames, etc. The zinc casing of dry batteries is the negative terminal. As zinc has a low melting point, it is being used for making die castings of small articles, e.g. bathroom fittings, door handles for cars, etc. As the mould is made of polished steel, the casting is fairly accurate in size, has a smooth surface, and does not require to be machined.

Tin is not attacked by air, water, or dilute acids at ordinary temperatures. Tin plate, which is sheet steel dipped in molten tin, is used for making 'tins', e.g. jam tins. Tinned copper is used for dairy utensils. Tooth paste tubes are made of tin.

Lead is a heavy metal which turns a dull grey on exposure to air. As it is malleable and resistant to corrosion, it is used for household plumbing, chemical plant (lead chambers for the manufacture of sulphuric acid), and for covering telephone and electrical cables. It is very slightly soluble, especially in soft water, and as its compounds are poisonous it cannot be used for tanks or pipes supplying water for domestic purposes. It is also used for making lead batteries or accumulators and for the manufacture of white lead (pigment in paints).

Copper is a reddish metal which is not readily corroded and is an excellent conductor of heat and electricity. It is used for electrical wires and switches, boilers, hot-water cylinders, utensils, car radiators, roofing, spouting and pipes, etc. As it is a comparatively soft metal, it is usually hardened by the addition of other metals, e.g. tin and zinc, to make bronze and brass respectively.

ALLOYS

When a metal has been melted with other metals and the whole mass solidified into a homogeneous material, the product is called an alloy. It may have properties which are intermediate between those of its constituents or new properties may appear owing to the formation of compounds. Generally an alloy is harder and has a lower melting point than the metals from which it is formed.

EXPERIMENT *Preparation of Wood's metal.*

In a crucible melt 10 grams of lead and then add to it 20 grams of bismuth, 5 grams of tin, and 5 grams of cadmium. If there is a groove in your ruler, lay it flat on your bench and stop up both ends with some plaster of Paris. Now pour the molten alloy into the mould so as to form a thin bar. If you use this to stir some water which is being heated in a beaker, you will find that it will melt well below the boiling point of water. The melting points of the metals from which you made it are: lead 327°, cadmium 321°, bismuth 271°, and tin 232°, and that of your alloy is 65°.

Wood's metal is used to seal holes in the pipes of the automatic sprinkler type of fire extinguisher fitted to the ceilings in many large buildings. Should a fire break out, the heat melts the Wood's metal plugs, allowing water from the mains to flow and extinguish the fire.

ALLOY STEELS

Nickel Steels. The addition of three per cent to four per cent of nickel imparts great toughness to steel. It is used for propeller and turbine shafts, explosive chambers of guns, armour plate, etc.

Chrome Steels. Chromium gives resistance to corrosion and hardness to steel. Stainless steel, which contains from eleven per cent to eighteen per cent of chromium, is used for cutlery, surgical instruments, ornamental fittings, chemical and household utensils, etc.

Nickel-chrome Steels. On account of their toughness and hardness, they are used extensively in the automobile industry.

Manganese Steel. This can be made so hard that it cannot be machined with ordinary equipment, and must be ground with an emery wheel. It is used in equipment subject to heavy wear, e.g. for railway points and crossings, and for teeth on dredge buckets and steam shovels. As it cannot be drilled and is not readily cut with an acetylene torch, it is used for safes and for doors of strong rooms.

Vanadium Steels. These are used for automobile springs.

Tungsten Steels and Cobalt Steels. These are used for making high-speed tools for lathes and similar equipment. They hold their cutting edge even when operated at red heat.

Nitralloy Steels. When special steels are heated in ammonia, the surface becomes very hard and is resistant to corrosion. It will scratch glass, and files have no action on it.

Non-Ferrous Alloys

Brass, which is a mixture of copper and zinc, has most of the desirable properties of copper, and in addition it is stronger and more malleable.

Bronze (copper and tin) is employed for those parts of machines where strength and resistance to corrosion are important. The propeller blades used on ships are made from phosphor bronze (90 per cent copper, 9·7 per cent tin, and 0·3 per cent phosphorus).

Coinage Metals. Copper coins consist of copper which has been hardened by the addition of tin and zinc. 'Silver' coins formerly contained 92·5 per cent of silver, but those now used are minted from a cupro-nickel alloy (75 per cent copper and 25 per cent nickel).

Duralumin (aluminium, copper, magnesium, and manganese) and *Magnalium* (aluminium and magnesium), are harder and stronger than aluminium, which they have replaced for most purposes. They are used principally for aircraft construction, parts of cars, etc. Magnalium is lighter than aluminium.

Solder, which consists of a mixture of tin and lead, melts at a lower temperature than either of these two metals. It is used for joining metals If antimony is added, the alloy is called '*type metal*', which, as it expands on cooling, takes clear impressions of type faces and is used in typesetting machines.

CHEMICAL PROPERTIES OF THE METALS

During your work in Science, you have examined some of the properties of the common metals, but it is now necessary to investigate these more systematically and thoroughly. The metals with which

we shall be dealing are sodium, calcium, magnesium, aluminium,* zinc, iron, lead, and copper.

EXPERIMENT *Action of the metals on the salts of the other metals.*

Prepare solutions of the following salts: sodium chloride, calcium chloride, magnesium sulphate, zinc sulphate, ferrous sulphate, lead nitrate, and copper sulphate. If you place an iron nail in a solution of copper sulphate, you will find that copper is deposited, and that the solution turns greenish blue. Test a sample of each of the solutions with an iron nail and make a note of the ones from which the metal is deposited. Different groups of the class should now investigate the action of the remaining metals on these solutions. (Omit sodium and calcium, as they would merely liberate hydrogen from the water.) The results obtained by the class should now be tabulated on the blackboard so that you may discuss the results in more detail.

	Mg	Zn	Fe	Pb	Cu
Sodium chloride					
Calcium chloride					
Magnesium sulphate					
Zinc sulphate					
Ferrous sulphate					
Lead nitrate					
Copper sulphate					

Use the results of this experiment to arrange the metals in order:

Metal which liberates 4 other metals from their salts .....

Metal which liberates 3 other metals from their salts .....

Metal which liberates 2 other metals from their salts .....

Metal which liberates 1 other metal from its salts .....

Metal which liberates 0 other metal from its salts .....

You will find that one metal (magnesium) is so reactive that it replaces four of the metals from their salts, but copper, on the other

*As the coating of oxide always present on aluminium protects it from the action of other substances, it is difficult to carry out the usual tests with this metal. Consequently it has been omitted from the experimental work.

hand, is so inert that it does not react at all. Use the information you have obtained to arrange the metals in order, commencing with magnesium and finishing with copper. You know that sodium is more reactive than calcium, and that calcium is more so than magnesium, so we can put these two metals at the beginning of our series.

This arrangement of the metals,

Na, Ca, Mg, Zn, Fe, Pb, Cu

is called the Replacement (or Electrochemical) Series. As you proceed further in Chemistry, you will find this series a very useful guide to the reactions of the metals.

We can now check our Replacement Series by revising some of the work we have already done in this course.

EXPERIMENT *Action of heat on metals.*

You know that sodium, calcium, and magnesium burn in air to form oxides, and you should now heat the remainder of the metals. As lead and zinc have low melting points, they should be heated in crucibles, but the remainder may be held on the outside edge or at the top of a bunsen flame, and the changes that occur should be noted. Is there a decrease in the rate or readiness with which the metals form oxides?

EXPERIMENT *Action of water on metals.*

We have observed that sodium and calcium react with cold water and that iron liberates hydrogen when heated in a current of steam. Place a sample of each of the other metals in a combustion boat and heat in a silica tube in a current of steam (*Fig. 25*). If a gas is produced, collect it, and apply a taper to the test-tube; also note any changes that take place in the appearance of the metal.

Here again you will observe that the readiness with which the metals react decreases until we reach copper, which has no action at all on water.

EXPERIMENT *Action of hydrochloric acid on metals.**

Try first of all the action of very dilute acid, and, if no reaction occurs, increase the strength, or even use concentrated acid, and warm slightly but do not boil.† In each case, hold your thumb over the mouth of a test-tube for one or two minutes, and then remove it while the mouth of the test-tube is held near a bunsen flame.

The results obtained again demonstrate the usefulness of the Replacement Series, as there is a definite decrease in the rate at which the metals react. The action of the acid on lead is so slight

*CAUTION: *DO NOT CARRY OUT ANY TESTS WITH SODIUM.*

†Hydrochloric acid is a solution of a gas in water, and if you boil it some of the gas will be driven out of the solution.

that it is difficult to test for the presence of hydrogen, and when we come to copper we know beforehand that there will be no action at all.

We can now summarize the results of these experiments.

1. In the Replacement Series, the metals are arranged in the order of their reactivity.

   Na, Ca, Mg, Al, Zn, Fe, Pb, Cu

2. Any metal will replace from its salts any metal that comes after it,

   e.g. iron replaces copper from copper sulphate.

   $$Fe + CuSO_4 = Cu + FeSO_4$$

   Magnesium replaces lead from lead nitrate.

   $$Mg + Pb(NO_3)_2 = Mg(NO_3)_2 + Pb$$

3. All metals in the Series, with the exception of copper, liberate hydrogen from water.

   (a) Sodium and calcium react with cold water, the *hydroxide* of the metal being formed.

   $$Ca + 2H_2O = Ca(OH)_2 + H_2$$

   (b) When magnesium, aluminium, zinc, iron, and lead are heated in a current of steam, the *oxide* of the metal will be formed.

   $$Zn + H_2O = ZnO + H_2$$

4. All metals in the series, with the exception of lead and copper, liberate hydrogen from hydrochloric acid and dilute sulphuric acid. There is a decrease in the rate with which they react.

   $$Mg + 2HCl = MgCl_2 + H_2$$

   $$Fe + H_2SO_4 = FeSO_4 + H_2$$

PHYSICAL PROPERTIES

	Na	Ca	Mg	Al	Zn	Fe	Pb	Cu
Melting point	97°	810°	650°	660°	420°	1500°	327°	1080°
Specific gravity	0·97	1·55	1·7	2·7	7·1	7·8	11·3	8·9
Percentage in earth's crust	2·5	3	2	7	·001	4	·001	·001
World production in millions of tons per year	0·3	·001	0·3	2	2	100	2	3

SUMMARY

<table>
<tr><th rowspan="2"></th><th rowspan="2">CHIEF ORE</th><th rowspan="2">METHOD OF EXTRACTION</th><th colspan="3">REACTIONS</th></tr>
<tr><th>WHEN HEATED</th><th>WITH WATER OR STEAM</th><th>WITH DIL. HCl</th></tr>
<tr><td>Na</td><td>NaCl</td><td rowspan="3">Electrolysis</td><td rowspan="4">Burn to form oxides.</td><td rowspan="2">Form hydroxide and hydrogen.</td><td rowspan="3">Form chlorides and hydrogen.</td></tr>
<tr><td>Ca</td><td>$CaCO_3$</td></tr>
<tr><td>Mg</td><td>$MgCO_3$</td></tr>
<tr><td>Al</td><td>Al_2O_3</td><td rowspan="2">Reduction with carbon.</td><td rowspan="3">Form oxide and hydrogen.</td></tr>
<tr><td>Zn</td><td>ZnS</td></tr>
<tr><td>Fe</td><td>Fe_2O_3</td><td rowspan="2">Heat sulphide</td><td rowspan="2">Form oxides when heated.</td><td rowspan="2">No action.</td></tr>
<tr><td>Pb</td><td>PbS</td></tr>
<tr><td>Cu</td><td>$CuFeS_2$</td><td></td><td></td><td>No action.</td><td></td></tr>
</table>

EXERCISE

Use your knowledge of the replacement series to write equations for the following reactions. If there is no action, say so.

	Pb	Ca	Fe	Mg	Zn
Hydrochloric acid					
Magnesium sulphate					
Water or steam					
Dil. sulphuric acid					
Heat in air					
Iron Sulphate					

SOME IMPORTANT COMPOUNDS

SODIUM HYDROXIDE (Caustic Soda) NaOH

EXPERIMENT *To study the properties of sodium hydroxide.*

Caution. As sodium hydroxide has a corrosive action on skin, it must be handled with a spatula.

1. After you have noted its appearance, place a few flakes on a watch glass and leave for ten minutes. Note any change. Now dissolve about 5 grams of it in 100 cc of water and use the solution for the following tests.
2. Rub some of the liquid between your thumb and forefinger.
3. Test with litmus.
4. Boil up 1 cc of olive oil with 5 cc of sodium hydroxide solution and when it is cool, try the effect of rubbing this liquid on your hands and then washing them with water. What has been formed?
5. Add sodium hydroxide to solutions of the following salts: magnesium sulphate, iron sulphate, lead nitrate, and copper sulphate. What substance is formed in each case?
6. Add sodium hydroxide to a little solid ammonium chloride or sulphate in a test-tube and heat. What is the gas that is evolved?

Properties

1. White deliquescent* solid.
2. Turns red litmus blue.
3. Has a 'soapy' feel.
4. Reacts with acids and acidic oxides to form salts.

$$NaOH + HCl = NaCl + H_2O$$

$$2NaOH + CO_2 = Na_2CO_3 + H_2O$$

5. Precipitates the hydroxides of most of the other metals.

$$CuSO_4 + 2NaOH = Cu(OH)_2 + Na_2SO_4$$

6. Reacts with fats to form soaps.
7. Liberates ammonia from ammonium salts.

$$NH_4Cl + NaOH = NaCl + H_2O + NH_3$$

*It absorbs so much moisture from the air that it forms a solution.

Uses

1. Manufacture of soap.
2. Cleansing agent.
3. Mercerization of cotton. If cotton is treated with a strong solution of sodium hydroxide, it develops a silky lustre.
4. Manufacture of rayon.

SODIUM CARBONATE (Washing soda) $Na_2CO_3.10H_2O$

EXPERIMENT *To study the properties of sodium carbonate.*

1. Select a clear crystal, and after you have noted its appearance place it in a test-tube fitted with a delivery tube. Heat the test-tube with its mouth sloping downwards and bubble into lime water any gas that may be liberated. How would you explain the changes you observed?

Use a solution of sodium carbonate for the following tests.

2. Test with litmus.
3. Heat the solution until it is nearly boiling.
4. Add an acid to a sample of it.
5. Add it to solutions of the following salts: magnesium sulphate, iron sulphate, lead nitrate, and copper sulphate.

Properties

1. White crystalline solid which crystallizes with ten molecules of water of crystallization.
2. When heated it loses its water of crystallization but does not decompose.
3. Soluble in water. The solution turns red litmus blue.
4. Acids liberate carbon dioxide.

$$Na_2CO_3 + H_2SO_4 = Na_2SO_4 + H_2O + CO_2$$

5. Precipitates the carbonates of most of the other metals.

$$Pb(NO_3)_2 + Na_2CO_3 = PbCO_3 + 2NaNO_3$$

Uses

1. Cleansing agent.
2. For softening hard water.
3. Manufacture of glass and paper.

Sodium Bicarbonate (baking soda) $NaHCO_3$

EXPERIMENT *To study the properties of sodium bicarbonate.*

Carry out the same tests you did with sodium carbonate.

Properties

1. White powder not very soluble in water.
2. Solution is alkaline.
3. Decomposes on heating.

$$2NaHCO_3 = Na_2CO_3 + H_2O + CO_2$$

4. Acids liberate carbon dioxide.

$$NaHCO_3 + HCl = NaCl + H_2O + CO_2$$

5 Precipitates the carbonates of most other metals.

$$MgSO_4 + 2NaHCO_3 = MgCO_3 + Na_2SO_4 + H_2O + CO_2$$

Uses

1. Leavening agent. As carbon dioxide is liberated when it is heated, it may be used on its own. Baking powder is a mixture of sodium bicarbonate and a dry acid or acid salt, e.g. cream of tartar, acid phosphate, etc.
2. 'Fruit salts' consist of a mixture of baking soda, an acid such as citric or tartaric acid, and a purgative, e.g. Glauber's salt.

PROBLEM Use the following equation to calculate how much tartaric acid should be mixed with 84 grams of bak'ng soda in order to prepare "fruit salts".

$$H_2C_4H_4O_6 + 2NaHCO_3 = Na_2C_4H_4O_6 + 2H_2O + 2CO_2$$

3. Constituent of soda acid fire extinguishers.

Copper Sulphate (bluestone) $CuSO_4.5H_2O$

EXPERIMENT *To study the properties of copper sulphate.*

1. Place some powdered copper sulphate in a crucible and heat gently until a white powder is formed. When cool, add a drop of water and note the colour. Now heat strongly until no further change takes place.

Use a solution of copper sulphate for the following tests:

2. Add ammonium hydroxide drop by drop. After you have noted the appearance of the precipitate, add excess ammonium hydroxide and shake.

3. Repeat the last test, but use sodium hydroxide instead of ammonium hydroxide. When complete, boil the liquid for a few minutes.

Properties

1. A blue crystalline solid which loses its water of crystallization when heated.
2. It decomposes when heated strongly.

$$CuSO_4 = CuO + SO_3$$

3. Soluble in water.
4. Ammonium hydroxide precipitates copper hydroxide which dissolves in excess ammonium hydroxide to form a cuprammonium compound, $Cu(NH_3)_4SO_4$.

$$CuSO_4 + 2NH_4OH = Cu(OH)_2 + (NH_4)_2SO_4$$

5. Sodium hydroxide precipitates copper hydroxide, which is not soluble in excess sodium hydroxide. The copper hydroxide decomposes on heating.

$$Cu(OH)_2 = CuO + H_2O$$

Uses

1. For killing fungi and moulds on plants, e.g. Bordeaux mixture.
2. Copper plating.

PROPERTIES OF SOME

CHEMICAL NAME	COMMON NAME	FORMULA
AMMONIUM		
Chloride	Sal ammoniac	NH_4Cl
Hydroxide	Spirits of hartshorn	NH_4OH
Sulphate	Sulphate of ammonia	$(NH_4)_2SO_4$
CALCIUM		
Carbonate	Limestone, chalk, marble, etc.	$CaCO_3$
Chloride		$CaCl_2$
Hydroxide	Slaked lime; the solution is called lime water	$Ca(OH)_2$
Oxide	Burnt lime, quick lime	CaO
Sulphate	Gypsum; plaster of paris is $(CaSO_4)_2.H_2O$	$CaSO_4.2H_2O$
COPPER		
Oxide		CuO
Sulphate	Bluestone	$CuSO_4.5H_2O$
IRON		
Sulphate	Green vitriol	$FeSO_4.7H_2O$
LEAD		
Carbonate	White lead	$PbCO_3$
Chloride		$PbCl_2$
Nitrate		$Pb(NO_3)_2$
Oxide	Litharge	PbO
	Red lead	Pb_3O_4
Sulphate		$PbSO_4$
MAGNESIUM		
Sulphate	Epsom salts	$MgSO_4.7H_2O$
POTASSIUM		
Carbonate		K_2CO_3
Chloride	Muriate of potash	KCl
Chlorate		$KClO_3$
Hydroxide	Caustic potash	KOH
Nitrate	Saltpetre	KNO_3
Permanganate	Condy's crystals	$KMnO_4$
Sulphate	Sulphate of potash	K_2SO_4
SILVER		
Chloride		$AgCl$
Nitrate		$AgNO_3$
SODIUM		
Bicarbonate	Baking soda	$NaHCO_3$
Carbonate	Washing soda	$Na_2CO_3.10H_2O$
Chloride	Common salt	$NaCl$
Hydroxide	Caustic soda	$NaOH$
Nitrate	Chile saltpetre	$NaNO_3$
Sulphate	Glauber's salt	$Na_2SO_4.10H_2O$
ZINC		
Carbonate		$ZnCO_3$
Sulphate	White vitriol	$ZnSO_4.7H_2O$

COMMON COMPOUNDS

SOLUBILITY at		USES
20°C	100°C	
37	77	Dry batteries; flux for soldering.
—	—	
75	103	Fertilizer.
Insoluble		Manufacture of burnt and slaked lime, glass, steel, and cement; agriculture and building.
75	160	Drying agent.
0·16	0·08	Mortar; neutralizing soil acids.
—	—	Tanning, agriculture; manufacture of chemicals.
0·2	0·16	Plaster casts, wallboard.
Insoluble		
21	75	Sprays, e.g. Bordeaux mixture, copper plating.
27	30	Blue-black ink.
Insoluble		Paint.
1	3	
57	139	
Insoluble		Manufacture of glass, pottery, and paint.
Insoluble		Manufacture of glass, pottery, and paint.
Insoluble		
26	41	Purgative.
53	61	
34	57	Manufacture of other potassium salts. Fertilizer.
7	57	Preparation of oxygen.
112	178	Manufacture of soft soap.
32	246	Fireworks, gunpowder, fertilizer.
6	—	
11	24	Fertilizer.
Insoluble		Manufacture of photographic emulsions.
222	952	
10	decomp.	Leavening agent, fruit salts. [etc.
22	46	Cleansing agent, water softener; manufacture of soap, glass,
36	40	Food; manufacture of other chemicals.
109	347	Manufacture of soap, cleansing agent.
88	180	Fertilizer.
19	43	Purgative; manufacture of glass.
Insoluble		
54	45	

9

Sulphur and Sulphuric Acid

NATIVE SULPHUR is found in most volcanic regions, but usually the quantity present is too small to warrant its collection and purification. Some years ago, an attempt was made to obtain this element from White Island but the venture was unsuccessful and was soon abandoned. At the present time we import annually between 60,000 and 70,000 tons, the bulk of which comes from Texas and Louisiana in the United States of America. Here it occurs in beds up to eight hundred feet below the surface. The sulphur is melted by superheated water and steam at 170°C, and forced to the surface with the aid of hot compressed air.

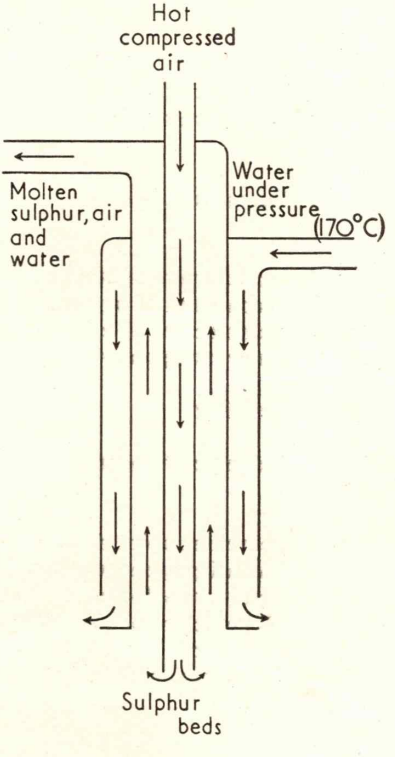


FIG. 29. The Frasch process for extracting sulphur.

Small quantities are also produced in Sicily, where sulphur occurs near the surface, mixed with earth and rock. When the crude material is heated, the sulphur melts and is run into moulds, where it solidifies.

Coal also contains sulphur, which can be recovered from the purifiers when coal gas is manufactured. As the gas-works in New Zealand are very small and widely scattered, no attempt has been made to recover this sulphur.

EXPERIMENT *Properties of sulphur.*

1. Examine samples of roll sulphur and flowers of sulphur and note their general appearance.
2. Heat some sulphur in a crucible until it melts. After you have noted the appearance of the liquid, ignite it with a bunsen flame.
3. Shake up some pieces of roll sulphur with water, carbon disulphide, alcohol, and benzene. In each case, pour the liquid into a watch glass, allow it to evaporate, and compare the quantities of sulphur deposited.
4. Mix together on an iron tray some sulphur and iron filings and then heat the mixture until no further change takes place. Examine the product and then test a sample of it with dilute hydrochloric acid. What gas is evolved?
5. In a mortar, grind together slaked lime and sulphur with a little water until a smooth paste is obtained. Add more water and boil the mixture in a beaker for about ten minutes. After you have removed the bunsen, allow the insoluble material to settle and examine the clear liquid. It is called lime sulphur solution and is used as a fungicide.

Sulphur is a yellow crystalline non-metallic element which melts at 114°C, and burns in air with a blue flame to form sulphur dioxide. It is insoluble in water but dissolves in a number of organic solvents, e.g. carbon disulphide. It combines directly with most elements to form sulphides.

Uses

1. Preparation of sulphur dioxide, which is used in the manufacture of sulphuric acid. See page 108.
2. Vulcanization of rubber. Raw rubber has very few uses, as it is readily oxidized by the air, is soluble in a number of petroleum solvents, and becomes tacky in hot weather and brittle at low temperatures. If sulphur is added to it, rubber loses many of its undesirable properties and becomes an elastic material which is stable to ordinary atmospheric temperature changes. If more sulphur is added, a hard substance called vulcanite is obtained. Formerly, this material was used for making fountain pens, combs, etc., but it has been very largely replaced by the synthetic plastics.

3. Fungicide. Large quantities of colloidal sulphur and lime sulphur solution are used for spraying fruit trees, grape vines, hops, and other plants to control various fungous diseases.
4. Manufacture of fireworks, gunpowder, and matches. Black powder consists of 75 per cent potassium nitrate, 15 per cent charcoal, and 10 per cent sulphur.
5. Medical. Manufacture of sulpha drugs, e.g. sulphanilamide, sulphadiazine, sulphathiazole, etc., which are used for treating a number of bacterial diseases.
   Sulphur ointment is used for treating skin diseases.

SULPHUR DIOXIDE

EXPERIMENT *Properties of sulphur dioxide.*

Jars of sulphur dioxide may be prepared by burning sulphur on deflagrating spoons in jars of air.

Carry out the usual tests for smell, appearance, litmus, taper, and solubility.

Place in a jar of the gas some red flowers or a dilute solution of magenta (a red dye), and leave them until the colour fades.*

Pour dilute solutions of (*a*) potassium dichromate and (*b*) potassium permanganate into separate jars of the gas and note the colour changes.

Finally, invert a jar of the gas over a dilute solution of sodium hydroxide.

Commercially sulphur dioxide is prepared by burning sulphur or by roasting metallic sulphides, e.g. iron pyrites FeS_2, zinc blende ZnS, galena PbS, or spent oxide from the gas works, in a current of air.

$$2ZnS + 3O_2 = 2ZnO + 2SO_2$$

Uses

1. Manufacture of sulphuric acid. See page 108.
2. Bleaching agent. It bleaches colouring matter by reducing it, i.e. it removes oxygen. It is used particularly for wool, silk, and straw, which would be injured by chlorine; but the bleaching may not be permanent, e.g. straw hats or woollen singlets bleached in this way become yellow when exposed to sunlight.
3. Germicide. The gas has been used as a fumigant for disinfecting premises after infectious diseases, and it is also one of the preservatives permitted under the New Zealand Food and Drug Regulations. You have probably seen on the label of a bottle of cordial the words, 'Contains not more than 2 grains of sulphur dioxide to the pint'.
   Sulphur dioxide is also used to preserve dried apricots, apples, etc.

*Not all flowers and dyes are bleached by sulphur dioxide.

4. Manufacture of 'sulphite' wood pulp for making paper, etc.

As sulphur compounds are used extensively in the manufacture of paper, the following brief account of the industry is included at this stage:

Manufacture of Paper in New Zealand

During the last fifty years very extensive pine plantations have been planted, chiefly on the pumice lands of the North Island. These trees have now reached the stage where the timber can be milled, and increasing quantities of it are being used for the manufacture of paper and cardboard. The three largest plants are situated at Kawerau (Tasman Pulp and Paper Co.), Kinleith (New Zealand Forest Products), and Whakatane (Whakatane Board Mills). (See *Plate 4.*)

As wood consists of bundles of cellulose fibres cemented together with a gummy substance called lignin, the first step in the paper-making process is to break it up into individual fibres. This is accomplished by:

1. *Grinding.* Four-foot logs are forced against huge grindstones, each of which is capable of producing thirty tons of pulp per day. Kawerau and Whakatane manufacture this type of pulp.

2. *Chemical processes.*

(a) Sulphate or Kraft Process. After the wood has been cut up into chips, it is digested in a solution containing sodium sulphide and sodium hydroxide which dissolves out the lignin and resins. Pulp is made by this process at Kawerau and Kinleith.

(b) Sulphite Process. This is important overseas, but is not used in New Zealand, as it is not very suitable for our wood. The resinous materials are dissolved out by boiling the wood chips in calcium bisulphite, which is prepared by saturating milk of lime with sulphur dioxide.

After the pulp has been thoroughly washed, it is poured onto a travelling wire-mesh screen, from which it is transferred onto a huge felt belt. On both of these, the excess water is sucked or squeezed out of the pulp. The film of moist paper then passes over steam-heated cylinders to dry it, and finally it is wound on to huge rolls. These are removed from the machine when they are about five feet in diameter. The paper-making machine can run at up to 2000 feet per minute, and at this speed the entire process from the wire screen to the winding up of the dried paper takes only forty-five seconds.

Newsprint is manufactured at Kawerau from a mixture consisting of eighty per cent ground wood pulp and twenty per cent semi-bleached sulphate pulp. The estimated annual production is 75,000 tons.

Cardboard is produced at the Whakatane Board Mills from a mixture of mechanical and chemical pulp.

Kinleith produces chiefly brown wrapping paper and pulp by the sulphate process. The plant is capable of producing 45,000 tons of pulp and 25,000 tons of kraft paper annually.

Hardboard and softboard for lining buildings are made by New Zealand Forest Products at their Penrose factory.

SULPHURIC ACID

Sulphuric acid is undoubtedly our most important chemical; in the United States alone nearly one million tons per month are produced. Approximately 300,000 tons of this acid are made and used annually in New Zealand for the manufacture of fertilizers alone. As sulphuric acid is a difficult substance to transport, it is usually made in the country in which it is to be used. (See *Plate 5.*)

EXPERIMENT *Properties of sulphuric acid.*

Before commencing this experiment, revise the general properties of acids in *General Science* (pp. 100-103).

1. Examine a bottle of concentrated sulphuric acid and note that it is a heavy oily liquid. It was formerly called 'oil of vitriol'.
2. Hold a beaker containing a small quantity of water on the palm of your hand and add to it 1 to 2 cc of concentrated acid.
   Caution. When preparing dilute sulphuric acid, the concentrated acid must be poured into water, and *not* vice versa.
3. Place a small quantity of sodium chloride in a test-tube and cover it with concentrated acid. Note the appearance and smell of the gas that is evolved.
4. Repeat the previous experiment, using sodium nitrate and concentrated acid. It may be necessary to warm the test-tube slightly.
5. Half fill a 150 cc beaker with cane sugar, and stir into it sufficient concentrated acid to moisten the whole mass. Place it on one side for one to two minutes, and observe the changes that take place.
6. Add a few drops of barium chloride solution to some dilute sulphuric acid.
7. Add 1 cc of concentrated acid to samples of copper, lead, and zinc. Warm the test-tube and note the smell and appearance of the gas evolved. Is it hydrogen?

MANUFACTURE OF SULPHURIC ACID

In New Zealand, most sulphuric acid is made by passing into huge lead chambers a mixture of sulphur dioxide, air, steam, and oxides of nitrogen. The sulphur dioxide is first of all oxidized to sulphur trioxide, which combines with the steam to form sulphuric acid.

$$SO_2 + NO_2 = SO_3 + NO$$

$$H_2O + SO_3 = H_2SO_4$$

The oxides of nitrogen are recovered and can be used over again. The liquid which is produced is impure, and contains only 70 per cent of sulphuric acid, but it is quite satisfactory for the manufacture of superphosphate. There are sulphuric acid plants in Auckland (3), Napier (1), New Plymouth (1), Wanganui (1), Christchurch

(1), and Dunedin (2). Plans have been prepared for the erection of additional works at Tauranga, Morrinsville, and Southland.

If a pure concentrated acid is required, the 'contact' process must be used. A mixture of sulphur dioxide and air is passed over a catalyst (vanadium pentoxide or platinum), and as the sulphur trioxide which is formed is difficult to dissolve in water, it is absorbed in concentrated sulphuric acid, which is later diluted down to the required strength. As the gases used must be pure so as not to poison the catalyst, a very pure acid of any required strength can be prepared. The Napier works produce 44,000 tons of 100 per cent acid annually by this process.

$$2SO_2 + O_2 = 2SO_3$$
$$H_2O + SO_3 = H_2SO_4$$

Uses

1. Manufacture of fertilizers. As rock phosphate is insoluble in soil water, it is not readily available to plants, and consequently gives a very slow response. However, if it is treated with sulphuric acid, it is converted into a soluble form which acts very quickly.

$$\underset{\text{Rock phosphate}}{Ca_3(PO_4)_2} + 2H_2SO_4 = \underset{\text{Superphosphate}}{Ca(H_2PO_4)_2} + 2CaSO_4$$

   In 1956 approximately one million tons of superphosphate were manufactured in New Zealand.
   When ammonia is neutralized with sulphuric acid, the fertilizer ammonium sulphate is formed.

$$2NH_4OH + H_2SO_4 = (NH_4)_2SO_4 + 2H_2O$$

   The annual world production of this fertilizer is approximately ten million tons.

2. 'Pickling' steel for tin-plating and galvanizing. Sheet iron is dipped in dilute sulphuric acid, which dissolves off the iron oxide and leaves a clean surface suitable for dipping in molten tin or zinc.

3. Electrolytic manufacture of zinc and copper. When zinc sulphate, which is obtained by dissolving zinc oxide in sulphuric acid, is electrolysed, metallic zinc is obtained. When a block of impure copper is connected to the positive terminal of an electric generator and suspended in a bath of sulphuric acid, pure copper will be deposited on the cathode (negative plate).

4. Lead accumulators consist of lead plates immersed in sulphuric acid.

5. Refining petroleum. Objectionable sulphur compounds are dissolved out with sulphuric acid.

6. Manufacture of explosives. When glycerine, toluene, phenol and cellulose are treated with nitric acid in the presence of concentrated sulphuric acid, the high explosives, nitroglycerine, TNT, trinitrophenol, and gun cotton are formed.

   CAUTION. These substances are extremely dangerous, so do not attempt to make them in your laboratory.

7. Manufacture of detergents. The sodium salts of a number of sulphonated oils are very useful cleansing agents as they lather readily in hard water.

8. Manufacture of nitric and hydrochloric acids. When sodium chloride and sodium nitrate are treated with concentrated sulphuric acid the corresponding acids are liberated.

9. Miscellaneous uses. When paper is treated with sulphuric acid, it becomes stiffer and translucent. In this form it is used as lunch paper and for wrapping foods.
   In the viscose process for the manufacture of artificial silk, the liquid obtained by dissolving cellulose in sodium hydroxide and carbon disulphide is solidified into fine threads, when it is forced through nozzles into a bath of sulphuric acid.
   When starch is boiled with dilute sulphuric acid, it is converted into glucose, which is used in brewing and in the manufacture of jams, sweets, etc.
   Soda acid fire extinguishers contain small bottles of sulphuric acid.

SULPHATES

All the common sulphates, with the exception of those of calcium, barium, and lead, are soluble in water. Sulphuric acid was formerly called oil of vitriol, and a number of its salts are still known as vitriols.

Copper sulphate	blue vitriol	$CuSO_4.5H_2O$
Iron sulphate	green vitriol	$FeSO_4.7H_2O$
Zinc sulphate	white vitriol	$ZnSO_4.7H_2O$

Other common sulphates are:

Sodium sulphate	Glauber's salt	$Na_2SO_4.10H_2O$
Magnesium sulphate	Epsom salts	$MgSO_4.7H_2O$
Calcium sulphate	Gypsum	$CaSO_4.2H_2O$
	Plaster of Paris	$(CaSO_4)_2.H_2O$

Preparation

1. Soluble sulphates are prepared by the usual methods, i.e. the action of sulphuric acid on the metal, metallic oxide, hydroxide, and carbonate.
2. Insoluble sulphates are prepared by double decomposition, i.e. by the action of a soluble sulphate, e.g. sulphuric acid or sodium sulphate, on a soluble salt of the metal.

$$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl$$

REVISION NOTES

SULPHUR

OCCURRENCE

Free

1. Underground deposits in Texas and Louisiana.
2. In the vicinity of volcanoes, e.g. Sicily, White Island (N.Z.).

Combined

1. Sulphide ores of metals, e.g. iron pyrites, zinc blende.
2. Sulphates, e.g. Gypsum, $CaSO_4.2H_2O$.
3. In many proteins, e.g. hair, egg albumen. The odours of onions and mustard are due to organic sulphur compounds.

EXTRACTION

1. In America the sulphur is melted with superheated water and pumped to the surface in a molten condition.
2. In Sicily the crude sulphur is heated in kilns. The molten sulphur which runs out solidifies in vats.
3. Recovered from coal-gas purifiers.

PROPERTIES

1. Yellow powder or crystalline solid.
2. Relative density 2.
3. Melting point 114°C.
4. Insoluble in water, but dissolves in carbon disulphide.
5. Burns in air with a blue flame.
6. No action on litmus.

REACTIONS

1. Burns in air. $S + O_2 = SO_2$
2. Combines with most elements to form sulphides: $Fe + S = FeS$

USES

1. Manufacture of sulphuric acid.
2. Fungicide.
3. Vulcanization of rubber.
4. Manufacture of fireworks, gunpowder, and matches.
5. Medical: sulpha drugs and sulphur ointment.

Sulphur Dioxide

OCCURRENCE

1. In the gases evolved by volcanoes.
2. In the air in industrial areas from the combustion of sulphur in coal.

PREPARATION

Commercial

1. Burning sulphur in air.

$$S + O_2 = SO_2$$

2. Roasting metallic sulphides in air.

$$2ZnS + 3O_2 = 2ZnO + 2SO_2$$

Laboratory

1. Burning sulphur in air.
2. Action of acids on sulphites.

$$Na_2SO_3 + 2HCl = 2NaCl + H_2O + SO_2$$

Compare with the preparation of carbon dioxide.

$$Na_2CO_3 + 2HCl = 2NaCl + H_2O + CO_2$$

PROPERTIES

1. Colourless gas with a sharp suffocating odour.
2. More than twice as dense as air.
3. Very soluble in water.
4. Neither burns nor supports combustion.
5. Acidic. Oxide of a non-metal.

REACTIONS

1. Combines with water to form sulphurous acid.

$$H_2O + SO_2 = H_2SO_3$$

2. Combines with bases to form salts (sulphites).

$$2NaOH + SO_2 = Na_2SO_3 + H_2O$$

3. In the presence of a catalyst, it combines with oxygen to form sulphur trioxide.

$$2SO_2 + O_2 = 2SO_3$$

4. Reducing agent. It bleaches by removing oxygen from the colouring matter.

$$H_2O + SO_2 + [O] = H_2SO_4$$

TESTS

1. Turns orange potassium dichromate green.
2. Decolorizes potassium permanganate.

USES

1. Manufacture of sulphuric acid (see p. 108).
2. Bleaching agent for wool, silk, and straw.
3. Manufacture of calcium bisulphite (wood pulp, and paper).
4. Germicide and food preservative.

Sulphuric Acid

OCCURRENCE

Does not occur naturally.

MANUFACTURE

1. *Contact Process.* When a mixture of sulphur dioxide and air is passed over a catalyst (vanadium pentoxide or platinized asbestos) there is formed sulphur trioxide, which is absorbed in concentrated sulphuric acid. The fuming sulphuric acid which is formed is diluted with water.
2. *Chamber Process.* A mixture of sulphur dioxide, steam, air, and oxides of nitrogen is passed into huge lead chambers where 70 per cent sulphuric acid is formed.

$$SO_2 + NO_2 = SO_3 + NO$$
$$H_2O + SO_3 = H_2SO_4$$

PROPERTIES

1. A dense, oily, highly corrosive liquid.
2. R.D. 1·84 B.P. 330°C.
3. Soluble in water in all proportions. Dilute sulphuric acid is prepared by adding the concentrated acid to water and not vice versa. As the concentrated acid has a powerful affinity for water, it is used as a drying agent for acidic and neutral gases.
4. Powerful acid.

REACTIONS

1. As an acid. It reacts with metals, metallic oxides, hydroxides, and carbonates to form salts (sulphates).

$$Zn + H_2SO_4 = ZnSO_4 + H_2*$$
$$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$$

2. As a dehydrating agent. It removes the elements of water from sugar.

$$C_{12}H_{22}O_{11} = 12C + 11H_2O$$

3. Liberates volatile acids from their salts.

$$NaCl + H_2SO_4 = NaHSO_4 + HCl$$
$$NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3$$

4. As an oxidizing agent.

$$C + 2H_2SO_4 = CO_2 + 2H_2O + 2SO_2$$

TEST

Sulphuric acid and sulphates give a white precipitate when added to a solution of barium chloride.

$$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl$$

USES

1. Manufacture of fertilizers (superphosphate and ammonium sulphate).
2. 'Pickling' of steel for galvanizing and tinplating.
3. Electrolyte in the extraction of metals, electroplating, etc.
4. Electrolyte in lead accumulators.
5. Manufacture of explosives, detergents, nitric and hydrochloric acid, etc.
6. Removing sulphur compounds from petroleum.

---

*Hydrogen is not liberated if concentrated sulphuric acid is used.
$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2$

100

Ammonia and Nitric Acid

AMMONIA

EXPERIMENT *Action of alkalis on ammonium salts.*

Place a small quantity of ammonium chloride in a test-tube and cover it with a solution of sodium hydroxide. Warm the test-tube gently and note the smell of the gas that is evolved.

CAUTION On no account should you hold your nose over a vessel containing an unknown substance. Always waft some of the gas towards your nose, and even then you should smell it very carefully. You will probably recognize that the gas has a smell similar to that of household ammonia.

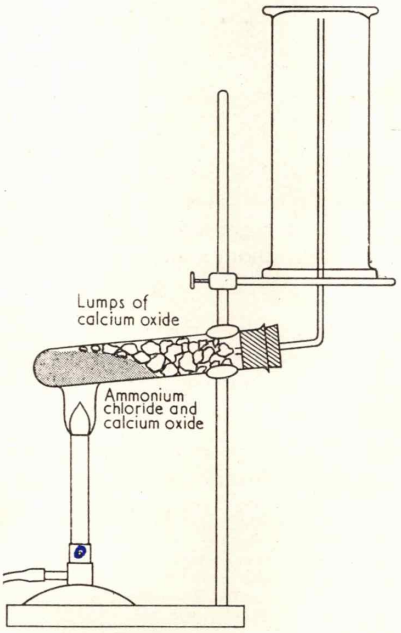


FIG. 30. The preparation of ammonia.

If you repeat the experiment, using ammonium sulphate instead of the chloride, you will find that ammonia is again liberated. Other alkalis, e.g. calcium hydroxide, will also liberate ammonia from its compounds.

EXPERIMENT *Preparation and properties of ammonia.*

Half-fill a hard glass test-tube with a mixture of ammonium chloride and calcium oxide, and then loosely pack the remaining space with small lumps of burnt lime to absorb the moisture which is formed in the reaction. As the gas is lighter than air and extremely soluble in water, it must be collected by the downward displacement of air.

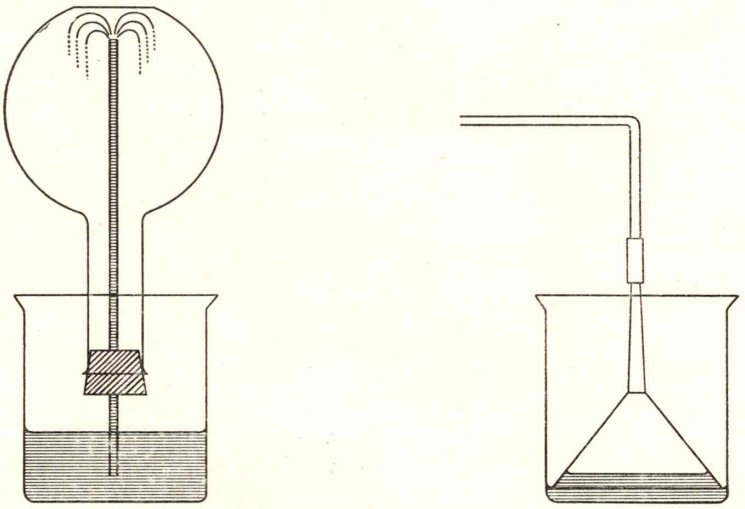


FIG. 31. (a) Fountain experiment; (b) Preparation of a solution of ammonia.

You can tell when a jar is full, as a piece of moistened red litmus paper, held near its mouth, will then turn blue instantly. After you have collected several jars of the gas, carry out the usual tests, viz. S–A–L–T–S.* The following additional experiments should be performed also:

1. Dip a piece of filter paper in a small quantity of concentrated hydrochloric acid, and then hold it in the mouth of one of the jars of ammonia. The dense white fumes which are formed consist of ammonium chloride.

---

*S *S*mell
A *A*ppearance
L Effect on *L*itmus
T Place a burning *T*aper in the gas
S Test *S*olubility by inverting a jar of gas over water

2. Place 2-3 cc of ammonia forte (see page 120) in a 500-cc flask and heat it carefully until the liquid has been vaporized. By that time, the ammonia will have filled the flask and completely displaced the air from it. Quickly insert a rubber stopper through which passes a piece of glass tubing, and invert the flask over water containing 1-2 cc of the indicator, phenolphthalein. The ammonia, which is extremely soluble, dissolves in the water, with the result that the pressure of the atmosphere forces a stream of water into the flask. As the ammonia is alkaline, it turns the phenolphthalein pink.

3. The ammonia in your reagent bottles is a solution of the gas in water but it cannot be prepared by simply passing the gas through the delivery tube into water. As the previous experiment demonstrated, the gas is so soluble that special precautions must be taken to prevent the water being forced up the delivery tube. After you have filled all your collecting jars, connect a filter funnel to the end of the delivery tube and invert it in a *small* amount of water in a beaker as shown in the diagram. At the end of the experiment, carefully smell the liquid and then test it with red litmus. Use this liquid for the next two tests.

4. To a solution of magnesium sulphate, add some of the ammonia solution. What is the precipitate which is formed?

5. Place a few drops of olive oil on the palm of your hand and then add a little of your ammonia solution. After you have rubbed the two liquids together, wash your hands under the tap and note if the oil has been removed.

Properties of Ammonia

Ammonia is a colourless gas which has an unpleasant, characteristic odour. It is extremely soluble in water, with which it forms a compound called ammonium hydroxide.

$$NH_3 + H_2O = NH_4OH$$

The ammonium radical NH_4 cannot exist by itself and is found only in compounds. If you compare these substances with the corresponding sodium salts, you will see that the ammonium group behaves as if it were a metal.

Ammonium hydroxide	NH_4OH	$NaOH$	Sodium hydroxide
Ammonium chloride	NH_4Cl	$NaCl$	Sodium chloride
Ammonium nitrate	NH_4NO_3	$NaNO_3$	Sodium nitrate
Ammonium sulphate	$(NH_4)_2SO_4$	Na_2SO_4	Sodium sulphate

In the experimental work, you found out that its hydroxide is an alkali which will precipitate insoluble hydroxides.

$$MgSO_4 + 2NH_4OH = Mg(OH)_2 + (NH_4)_2SO_4$$

Manufacture of Ammonia

In the section dealing with the destructive distillation of coal,* it was mentioned that ammoniacal liquor was one of the by-products. However, the quantity produced by this method is insufficient to supply our requirements, and the bulk of it is now manufactured by the Haber-Bosch process. (See *Plate 6.*)

When steam and a limited supply of air are blown through red-hot carbon, the resulting gas consists of nitrogen, hydrogen, and carbon monoxide.

$$2C + O_2 = 2CO$$

$$C + H_2O = CO + H_2$$

More steam is then added, and the gases are passed over an iron oxide catalyst. This produces more hydrogen, and converts the carbon monoxide into carbon dioxide.

$$CO + H_2O = CO_2 + H_2$$

As the carbon dioxide is not required, it is dissolved out in water in which it is more soluble than the other gases. The nitrogen and hydrogen, which are now in the proportion of 1 : 3, are compressed to 200 atmospheres (3000 pounds per square inch) and forced over an iron catalyst in a converter, when 15 per cent of the gases combine to form ammonia. This is usually:

1. Converted into ammonium sulphate.
2. Oxidized to nitric acid by mixing it with air and passing it through platinum gauze.

$$4NH_3 + 5O_2 = 4NO + 6H_2O$$

$$4NO + 3O_2 + 2H_2O = 4HNO_3$$

Uses of Ammonia

1. Manufacture of nitric acid.
2. Manufacture of ammonium sulphate. If your school has well-cared-for playing fields, it is probable that they are given a dressing of fertilizer every year; one of the most important substances for this purpose is sulphate of ammonia. You can demonstrate the action of sulphate of ammonia on grass very easily. Mark off with pegs one or two square yards of a lawn which have become brown, and scatter over the marked area a few handfuls of ammonium sulphate. After you have watered the ground thoroughly to wash the fertilizer into the soil, leave it for a week and then compare it with the surrounding lawn.

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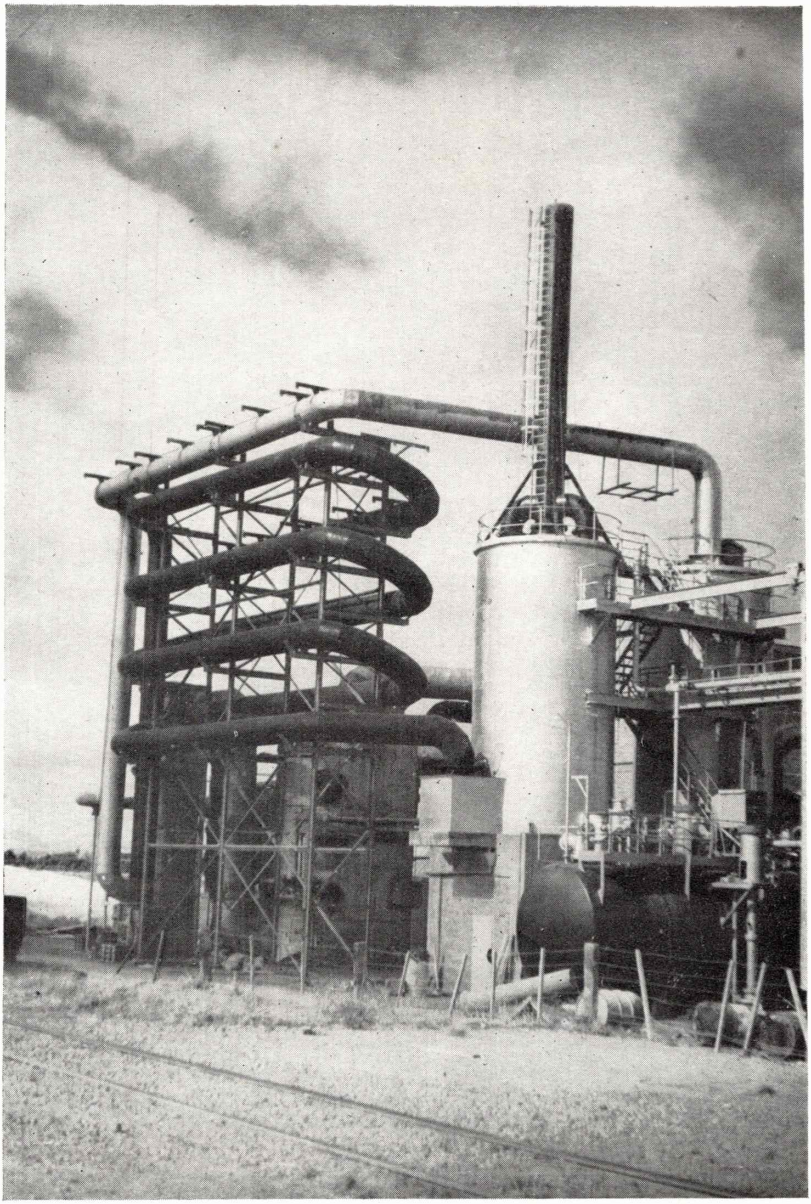
*See *General Science*, pp. 218-220



EAST COAST FARMERS' FERTILISER CO.

5. *Sulphuric acid plant* (Page 108)

I.C.I. A.N.Z.

6. The tower structure of a synthetic ammonia plant (Page 118)

Farmers whose properties carry stock are dependent upon the quality of the grass in their pastures. As you saw in the above simple test, sulphate of ammonia has a profound effect on growth, and farmers all over the world use tremendous quantities of this fertilizer, particularly on their grasslands.

The essential element in this compound is nitrogen, which was formerly supplied to the soil in the form of farmyard manure. When this material decays, the bacteria in the soil convert it into ammonia and into nitrates which can be absorbed by the plants.

3. Although ammonia is a gas, it is easily compressed into a liquid, and consequently it is widely used as a refrigerant in commercial refrigerators.

4. In the experimental work, you observed that ammonia converted olive oil into a soluble substance which could be washed off your hands. Also, it will soften temporarily hard water by precipitating the calcium bicarbonate as carbonate.

$$2NH_4OH + Ca(HCO_3)_2 = CaCO_3 + (NH_4)_2CO_3 + 2H_2O$$

The household ammonia which you buy at the grocer's is simply a weak solution of ammonia gas in water.

5. Manufacture of other ammonium compounds:

Ammonium chloride (sal-ammoniac) is used in dry cells and as a flux in soldering.

Ammonium nitrate is a constituent of some explosives. When it is heated, nitrous oxide is evolved. This gas is one of the anaesthetics used by dentists.

REVISION NOTES

AMMONIA

OCCURRENCE

Ammonia is formed during the decomposition of organic matter in the soil.

PREPARATION

Commercial

1. Haber-Bosch Process.

$$N_2 + 3H_2 = 2NH_3$$

2. By-product in the destructive distillation of coal.

Laboratory

By heating an ammonium salt with a strong base.

$$NH_4Cl + NaOH = NaCl + NH_3 + H_2O$$

$$2NH_4Cl + CaO = CaCl_2 + 2NH_3 + H_2O$$

PROPERTIES

1. Colourless gas with a characteristic pungent odour.
2. Lighter than air.
3. Extremely soluble in water. 1 cc of water at 0°C will dissolve 1100 cc of the gas.

   A saturated solution of the gas in water is called ammonia forte or 880 ammonia. (The solution has a relative density of 0·880.)
4. Does not support combustion but will burn in oxygen.
5. Turns red litmus blue. It is an alkali.

REACTIONS

1. It combines with water to form ammonium hydroxide.

$$NH_3 + H_2O = NH_4OH$$

2. It combines with acids to form salts.

$$NH_3 + HCl = NH_4Cl$$

3. It will precipitate insoluble hydroxides.

$$2NH_4OH + MgSO_4 = Mg(OH)_2 + (NH_4)_2SO_4$$

4. It will burn in oxygen.

$$4NH_3 + 3O_2 = 2N_2 + 6H_2O$$

5. When a mixture of ammonia and oxygen is passed through platinum gauze, nitric oxide is formed. This is part of the process for the manufacture of nitric acid from ammonia.

$$4NH_3 + 5O_2 = 4NO + 6H_2O$$

TESTS

1. Characteristic smell.
2. It is the only common gas that will turn red litmus blue.
3. Forms dense white fumes of ammonium chloride with hydrochloric acid.

USES

1. Manufacture of ammonium salts, e.g. ammonium sulphate.
2. Manufacture of nitric acid.
3. Liquid ammonia is used as a refrigerant.
4. Household ammonia is a weak solution of ammonia in water. It is used as a cleansing agent and for softening hard water.

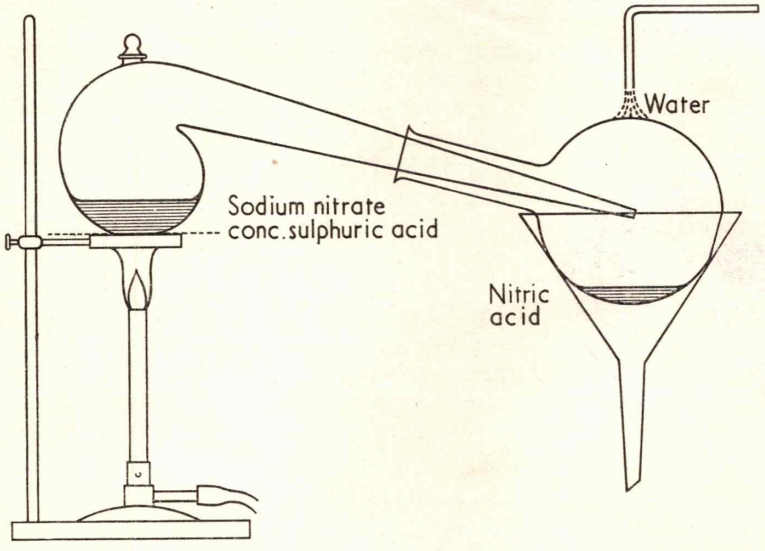


FIG. 32. The preparation of nitric acid.

NITRIC ACID

EXPERIMENT *Preparation and properties of nitric acid.*

Place some sodium nitrate in a retort and cover it with concentrated sulphuric acid. Now connect up the apparatus as shown in the diagram. As nitric acid has a corrosive effect on cork and rubber, these materials cannot be used, so that it is necessary to use all glass apparatus in the preparation of this acid. Heat the retort, and after you have noted the general appearance of the liquid which collects in the flask, use it to carry out the following tests:

1. Add it to a small quantity of water and test the solution with litmus.
2. Add the acid to samples of carbonates, e.g. sodium carbonate, calcium carbonate, etc. What gas is evolved?
3. To small pieces of different metals, e.g. magnesium, zinc, lead, and copper, add the dilute acid and warm the test-tube if necessary. What is the appearance of the gas that is given off in each case?
4. Boil a small quantity of concentrated nitric acid in a wide-mouthed flask and when it is filled with the vapour, hold a burning splint in it. The splint continues to burn in the oxygen it obtains from the nitric acid, and at the same time the acid is reduced to the brown gas,* nitrogen peroxide, which you can observe being formed in the flask.

$$C + 4HNO_3 = CO_2 + 2H_2O + 4NO_2$$

Observe that the carbon has been oxidized to carbon dioxide.

*Do not breathe in this gas as it is very poisonous.

Synthetic Nitric Acid

Up until 1914 practically all nitric acid was made from sodium nitrate, but when Germany was blockaded by England she was compelled to look for other sources of supply, as nitric acid was essential for the manufacture of explosives.

The supply of nitrogen in the air is free and inexhaustible, but the principal difficulty was to make it combine with other elements to form compounds from which nitric acid and nitrates could be obtained.

Prior to the 1914 war, the Birkeland-Eyde Process had been developed, principally in the Scandinavian countries. When air, or a mixture of equal parts of nitrogen and oxygen is forced through an electric arc, the two gases combine to form first of all nitric oxide and then nitrogen peroxide, which will dissolve in water to form nitric acid.

$$N_2 + O_2 = 2NO$$
$$2NO + O_2 = N_2O_4$$
$$H_2O + N_2O_4 = HNO_3 + HNO_2$$

However, this process uses enormous quantities of electrical energy, and as Germany is poorly provided with water power, her chemists developed the Haber-Bosch process, in which ammonia is formed by compressing a mixture of hydrogen and nitrogen and passing it over a catalyst. This compound can be converted into oxides of nitrogen by mixing it with air and passing it through a platinum gauze catalyst, so that the result is similar to that of the earlier process. Several other processes for 'fixing' atmospheric nitrogen have been developed, but the Haber-Bosch is still the most important. Since then, plants using this process have been built in most of the industrial countries, so that we are no longer dependent upon Chile for our supply of nitrates. One of the largest plants is owned and operated by Imperial Chemical Industries at Billingham in England.

Uses of Nitric Acid

1. Manufacture of fertilizers, e.g. sodium, potassium, calcium, and ammonium nitrates.
2. Manufacture of explosives. Until the advent of the atomic bomb, all industrial and military explosives were substances containing nitrogen. Many of the compounds formed by nitrogen are not particularly stable, and when they are subjected to a shock they rapidly break up, producing large volumes of gas which can be used to do very effective work. With the aid of explosives, canals

and tunnels can be built, coal and other minerals obtained from mines, and the rocks used for roads, buildings, etc. can be blasted from quarries.

There are two principal types of explosive:

a. Propellent explosives, which burn rapidly. To do effective work, this type of explosive must be placed in a confined space, e.g. cordite in cartridge and shell cases, and black powder tamped into holes drilled in rock.

b. High explosives, which detonate, so that they can be used for demolition work even out in the open, e.g. a railway rail can be cut in two if a slab of gun cotton is tied on to the side of the rail and set off with a suitable detonator. Other well-known high explosives are nitro-glycerine, TNT,* and trinitro-phenol, and they are all made by treating the appropriate chemical with nitric acid in the presence of concentrated sulphuric acid.

3. When cellulose is treated with nitric and sulphuric acids for a shorter time than that required to produce gun cotton, there is produced a nitrocellulose which is soluble in organic solvents. When the solution is mixed with pigments, it is known as a lacquer, and if a thick solution is spread on cloth and pressed to give it a grain, the product is artificial leather.
Celluloid is made by heating a mixture of nitrocellulose and camphor. This was one of our first plastics, and although it is very inflammable, it is still used for cinematograph films.

4. Manufacture of dyes. When benzene is treated with nitric acid, there is formed nitrobenzene which can be readily reduced to aniline. This is the substance from which many of our synthetic dyes are obtained.

5. Cleaning and etching metals. Nitric acid will dissolve all metals except the noble metals (gold, platinum, etc.), and even these will dissolve in a mixture of nitric and hydrochloric acids (*aqua regia*). If a piece of copper is coated with Brunswick black or paraffin wax, and a design cut through this layer with a sharp instrument, the copper will be eaten away by the nitric acid only in those places where the metal is exposed, i.e. the design will be etched in the copper.

NITRATES

As the nitrates of all metals are soluble in water, they may be prepared by the usual methods, viz. action of nitric acid on metals, metallic oxides, hydroxides, and carbonates.

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*Trinitrotoluene

However, nitric acid differs from the other acids we have studied in that metals generally do not liberate hydrogen from the dilute acid. This is because nitric acid is a powerful oxidizing agent, and any hydrogen which may be liberated is immediately oxidized to water. However, if the acid is very dilute, sodium, calcium, and magnesium will liberate some hydrogen from the acid.

$$Mg + 2HNO_3 = Mg(NO_3)_2 + H_2$$

The normal reaction between metals and dilute nitric acid is:

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 4H_2O + 2NO$$

When concentrated nitric acid is used, nitrogen peroxide will be liberated.

$$Cu + 4HNO_3 = Cu(NO_3)_2 + 2H_2O + 2NO_2$$

With oxides, hydroxides, and carbonates, the reactions proceed quite normally.

$$CuO + 2HNO_3 = Cu(NO_3)_2 + H_2O$$

$$NaOH + HNO_3 = NaNO_3 + H_2O$$

$$CaCO_3 + 2HNO_3 = Ca(NO_3)_2 + H_2O + CO_2$$

Sodium Nitrate (Chile Saltpetre)

The only region where this salt is found abundantly is in Chile, in a desert on the western slopes of the Andes. The bed, which is two hundred miles long, two miles wide, and two to five feet deep, was probably formed by organic matter decaying in contact with salt deposits, and as the region is practically rainless, the compound has not been washed away.

The rock, which is called caliche, is broken up with explosives, crushed, and then treated with water to dissolve out the sodium nitrate. After the insoluble material has settled to the bottom, the solution is evaporated to dryness. As it is hygroscopic* it cannot be used in gunpowder. It is used, (a) as a fertilizer, (b) in the manufacture of nitric acid, and (c) in the preparation of potassium nitrate.

Potassium Nitrate (Saltpetre or Nitre)

In the neighbourhood of many Indian villages, where the sewage disposal is very crude, the soil becomes saturated with decaying organic matter which is converted into nitrates by the nitrifying bacteria in the soil. When wood ash is added to it, a crude form of saltpetre is obtained. After purification, about 20,000 tons are produced annually by this method.

*Absorbs water vapour from the air.

However, most saltpetre is manufactured by a double decomposition reaction in which concentrated solutions of sodium nitrate (from Chile) and potassium chloride (from Stassfurt deposits) are mixed.

$$KCl + NaNO_3 = KNO_3 + NaCl$$

At boiling point, sodium chloride is the least soluble salt so it separates out, leaving the potassium nitrate, which is purified by recrystallization. It is used principally for the manufacture of gunpowder and fireworks.

Calcium Nitrate and Ammonium Nitrate

These are made from synthetic nitric acid, and are used in some countries as nitrogenous fertilizers. Ammonium nitrate is also used in the manufacture of nitrous oxide (anaesthetic), and of explosives, e.g. ammonal (ammonium nitrate and aluminium powder) and amatol (ammonium nitrate and TNT).

Silver Nitrate

This is prepared by dissolving silver in nitric acid. It is used, (a) for silvering mirrors, (b) for preparing silverplating solutions, (c) for the manufacture of photographic emulsions for plates, films, and printing papers, (d) in the laboratory test for chlorides, (e) for marking ink. When silver nitrate comes in contact with cloth, skin, etc., there is deposited finely-divided metallic silver, which is very difficult to wash off. Put a drop of the solution on your hand and leave it for a few minutes. Now try to wash it off.

REVISION NOTES

Nitric Acid

OCCURRENCE

Formed in the atmosphere during electrical storms.

PREPARATION

Commercial

1. Birkeland-Eyde Process.
2. Haber-Bosch Process and the oxidation of the ammonia.

Laboratory

Action of concentrated sulphuric acid on a nitrate.

$$H_2SO_4 + NaNO_3 = NaHSO_4 + HNO_3$$

PROPERTIES

1. Colourless liquid which fumes in air.
2. R.D. = 1·5 B.P. = 86°C
3. Soluble in water in all proportions.
4. Strong acid.

REACTIONS

1. Reacts with metals, metallic oxides, hydroxides, and carbonates to form salts (nitrates).

   NOTE. Metals, with the exception of sodium, calcium, and magnesium, do not liberate hydrogen from dilute nitric acid.

   Dilute nitric acid on metals.

   $$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 4H_2O + 2NO$$

   Concentrated nitric acid on metals.

   $$Cu + 4HNO_3 = Cu(NO_3)_2 + 2H_2O + 2NO_2$$

   Nitric acid on metallic oxides, hydroxides, and carbonates.

   $$ZnO + 2HNO_3 = Zn(NO_3)_2 + H_2O$$
   $$Ca(OH)_2 + 2HNO_3 = Ca(NO_3)_2 + 2H_2O$$
   $$Na_2CO_3 + 2HNO_3 = 2NaNO_3 + H_2O + CO_2$$

2. Powerful oxidizing agent, e.g. it oxidizes carbon to carbon dioxide.

   $$C + 4HNO_3 = CO_2 + 2H_2O + 4NO_2$$

3. Forms nitro-compounds with many organic substances, e.g. nitrocellulose, nitroglycerine, etc.

USES

1. Manufacture of fertilizers and explosives.
2. Production of nitrocellulose which is used for making duco, lacquer, nail polish, aeroplane dope, celluloid, artificial leather, etc.
3. Preparation of nitrobenzene and aniline from which dyes are made.
4. Etching metals.

II

Hydrochloric Acid and Chlorine

COMMON SALT

IN THE PAST New Zealand has imported annually approximately sixty thousand tons of salt from Australia, where it is obtained by the solar evaporation of sea water. A similar process has now been developed at Lake Grassmere in the Marlborough district, and there is every indication that this project will be able to supply a large proportion of our future needs. (See *Plate 7.*)

The plant consists of a series of huge shallow salt basins or fields, into which ordinary sea water is pumped. After the suspended matter has been deposited, the water is pumped into the next series of basins, where the concentration gradually increases, until the calcium sulphate is precipitated out. Further water is evaporated, and when the liquid contains 25 per cent to 28 per cent of salt it is pumped into the next set of fields, where the salt crystallizes out. The remaining liquor, which contains the more soluble salts, principally magnesium chloride, may be run back into the sea or treated in order to recover the metal magnesium and other by-products. After this process has been repeated a number of times, there collects in the crystallizers a thick layer of salt which is scraped into stacks, where it is allowed to drain. The salt obtained by this process is quite satisfactory for most industrial uses, but if it is required for domestic purposes, further purification is required. (See *Plate 8.*)

In some countries, e.g. England and Poland, there are huge deposits of rock salt which have probably been formed by the evaporation of inland seas. This rock salt is either mined, or dissolved *in situ* and the saturated solution pumped up to the surface, where it is filtered and evaporated in large open pans or in vacuum evaporators.

USES

1. *Food.* Usually the crude salt is recrystallized, and after it has been ground to the desired degree of fineness, up to one per cent of magnesium carbonate is added to keep it dry and free-running.

As most New Zealand soils are deficient in iodine, one part of sodium or potassium iodide in 20,000 is added to domestic salt to reduce the incidence of goitre.

As salt is being continually lost in perspiration, it is essential that more salt should be eaten by people living in hot climates than by those living in colder countries. Men doing heavy physical work in hot climates may lose in one day up to twenty pounds of sweat, which contains approximately one-half per cent (one and a half ounces) of salt. If this is not replaced, these men are liable to get cramp in the muscles and in the stomach, so the usual practice is to add salt to their drinking water, and give them more bacon, salt meat, and salt fish than they would consume normally. Salt licks are usually provided for farm animals, especially in hot weather. Blood contains about one-half per cent of salt.

Salt is used as a condiment to help develop the flavour and taste, particularly of meat and vegetables.

2. *Preservative.* A number of foods, e.g. meat, fish, beans, etc. can be preserved by covering them with a layer of salt. Practically all factory butter contains salt, which is added to develop its flavour and to improve its keeping qualities.
3. *Making Freezing Mixtures.* The temperature of melting ice is lowered by nearly 20°C if salt is added to it. Formerly, a mixture of ice and salt was used for freezing ice cream.
4. *Refrigerators.* In cool stores a saturated solution of brine, which has been cooled in a refrigerator, is circulated through pipes placed near the ceiling. Why are the coils in refrigerators placed at the top and not the bottom?
5. *Manufacture of Soap.* When salt is added to soap kettles, the soap rises to the surface and floats on the aqueous layer containing the salt and glycerine. The process is known as 'salting out'.
6. *Manufacture* of chlorine, hydrochloric acid, sodium, sodium carbonate, bicarbonate, hydroxide, and sulphate.
7. *Glazing of Earthenware.* When salt is put into the kiln in which the pottery is being heated, it vaporizes and combines with the surface layer of clay, forming a glassy layer of fusible silicates.

HYDROCHLORIC ACID

EXPERIMENT *Preparation and properties of hydrochloric acid.*

Set up the apparatus shown in Fig. 33, and after you have placed some sodium chloride in the flask, cover it with concentrated sulphuric acid, and quickly insert the cork. Effervescence takes place immediately, but later on it will be necessary to apply gentle heat to the flask.

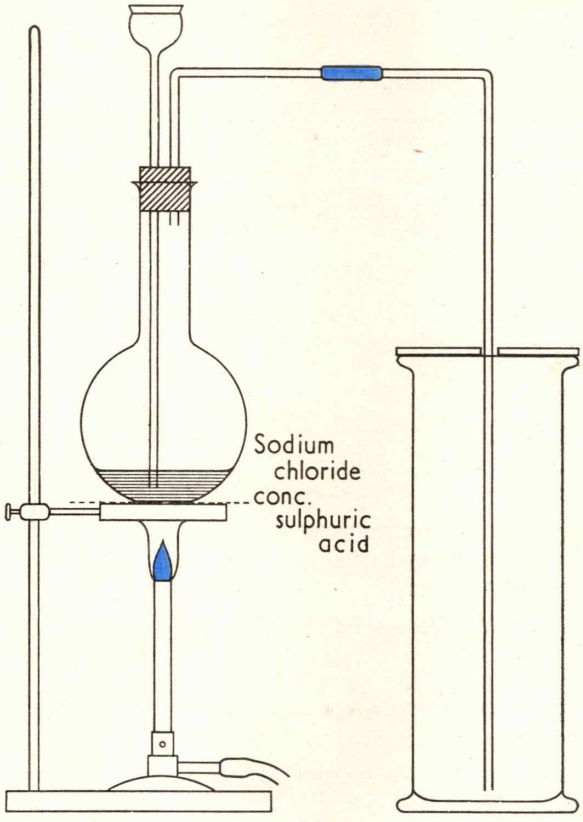

FIG. 33. The preparation of hydrochloric acid.

Collect several jars of the gas and carry out the usual tests, viz. S–A–L–T–S.* The following tests should also be done:

1. Place in another jar a small quantity of concentrated ammonia, and invert over it a jar of hydrogen chloride.
2. The hydrochloric acid used in the laboratory is a solution in water of the gas you have just prepared. As it is extremely soluble, special apparatus is required to prepare the solution. (If the end of the delivery tube were simply placed in a beaker of water, the gas would dissolve so rapidly that a partial vacuum would be formed in the flask, with the result that the atmospheric pressure would force the water up into the flask, where it would come in contact with the hot concentrated sulphuric acid.)

   Invert a funnel in a beaker containing about half an inch of water and connect the delivery tube to the stem of the funnel (see Fig. 31b).

*See page 116.

3. Test samples of the solution you have just prepared with:
   (a) Blue litmus.
   (b) Silver nitrate solution.
   (c) Warm it with manganese dioxide. Note the smell* and appearance of the gas that is evolved.
   (d) Add a piece of magnesium ribbon and hold the mouth of the test-tube near a bunsen flame. What gas is evolved?

CHLORIDES

Lead and silver chlorides are insoluble in water. Those of the other metals you have studied are soluble.

Preparation

1. Soluble chlorides are prepared by the usual methods, i.e. the action of hydrochloric acid on the metals, metallic oxides, hydroxides, and carbonates.
2. Insoluble chlorides are prepared by a double decomposition reaction, e.g. action of hydrochloric acid or a soluble chloride on a soluble salt of the metal.

$$AgNO_3 + HCl = NaNO_3 + AgCl$$

Tests

1. Soluble chlorides give a white precipitate with a solution of silver nitrate.
2. Chlorine is liberated when chlorides are heated with a mixture of manganese dioxide and concentrated sulphuric acid.

Uses

1. Sodium chloride (see pages 127-8).
2. Potassium chloride, which occurs in the Stassfurt deposits, is an important fertilizer.
3. Calcium chloride is present in most natural waters. It is used as a drying agent for gases.
4. Magnesium chloride, which occurs in sea water, is the material from which magnesium is obtained.
5. Silver chloride turns violet on exposure to light. Photographic plates and films consist of a suspension of silver salts in gelatine.
6. Ammonium chloride (sal-ammoniac) is used in dry batteries and as a flux in soldering.

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*This gas is very poisonous.

CHLORINE*

EXPERIMENT *Preparation and properties of chlorine.*

After you have placed in a flask some concentrated hydrochloric acid and manganese dioxide, agitate and stir the mixture in order to make sure that the powder has been thoroughly moistened. Now connect up the apparatus as shown in the diagram.

NOTE As the gas is very poisonous, it is advisable to use a Frankland's gas jar cover, which can be made from plaster of Paris or perspex. The hole in the centre should be sufficiently large to take a double-bored cork, and the glass tubes through this cork should slide freely. When the gas jar is full, simply slide out the long tube and slip a cover slip between the gas jar and the special cover, which is then lifted off and placed on a fresh gas jar.

The other portion of the apparatus consists of a gas jar filled with glass wool which has been mixed with a suitable absorbent, e.g. soda lime, for acid gases. Slide a piece of glass tubing down the side of the gas trap and connect it to the rest of the apparatus with rubber tubing. You can also use the apparatus for collecting a gas lighter than air, but in this case you would connect the short tube to the flask and the long tube to the gas trap. The special cover should be perfectly flat on the lower surface and should be made gas-tight with a layer of grease. Provided you use this or a similar type of apparatus, very little chlorine should escape into the air.

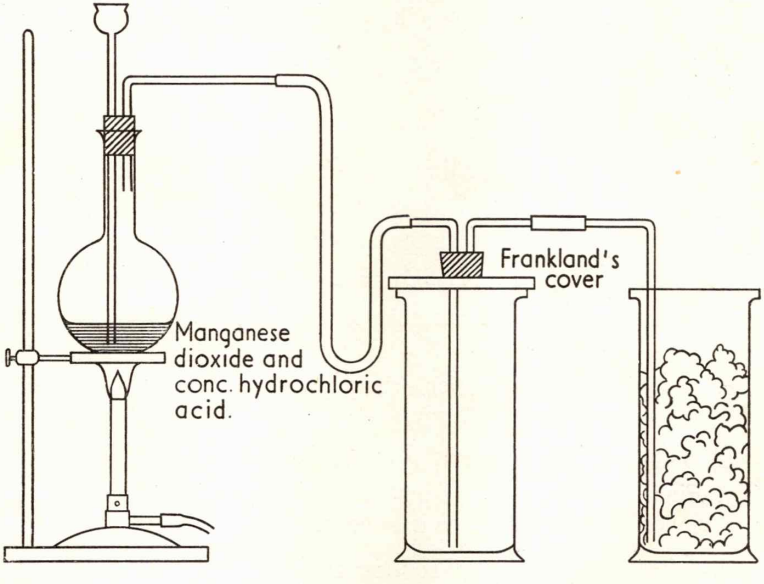

FIG. 34. The preparation of chlorine.

*Chlorine need not be studied for S.C. General Science examination.

Heat the flask until several jars of gas have been collected and then make the usual tests, viz. S–A–L–T–S.*

1. After you have moistened a piece of coloured cloth, paper on which you have written with ordinary ink, and a flower, place them in a jar of the gas and leave them for 5-10 minutes.
2. Place a piece of white phosphorus on a deflagrating spoon and hold it in a jar of the gas.
3. Into another jar of the gas drop a piece of 'Dutch metal' (an imitation gold leaf which consists chiefly of copper). The white fumes which are produced consist of copper chloride in a finely-divided state.
4. From a Kipp's apparatus, pass hydrogen sulphide into a jar of chlorine. Note the deposit of sulphur.
5. Pour a solution of potassium iodide into another jar of the gas. You can demonstrate that the brown colour is caused by iodine, as it gives a blue colour with starch.

Uses

1. Powerful bleaching agent, used particularly for vegetable fibres such as cotton, linen, wood pulp, etc. It reacts with water, liberating nascent oxygen which oxidizes the colouring matter.

$$H_2O + Cl_2 = 2HCl + [O]$$

In a commercial plant, the cloth is run through tanks containing the following chemicals:

a. Water, which wets it.

b. A suspension of bleaching powder.

c. A dilute acid, which reacts with the bleaching powder in the fibres of the cloth, liberating chlorine.

$$CaOCl_2 + H_2SO_4 = CaSO_4 + H_2O + Cl_2$$

d. Water to wash out the surplus bleaching powder, acid, and chlorine.

e. A solution of an 'antichlor', to destroy any residual chlorine which would rot the fabric.

f. Water, which washes out the antichlor.

g. Finally it is passed through an oven to dry it, and over heated rollers to press it before it is wound on to a roller.

In America, a solution of sodium hypochlorite is used instead of bleaching powder.

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*See footnote, page 116.

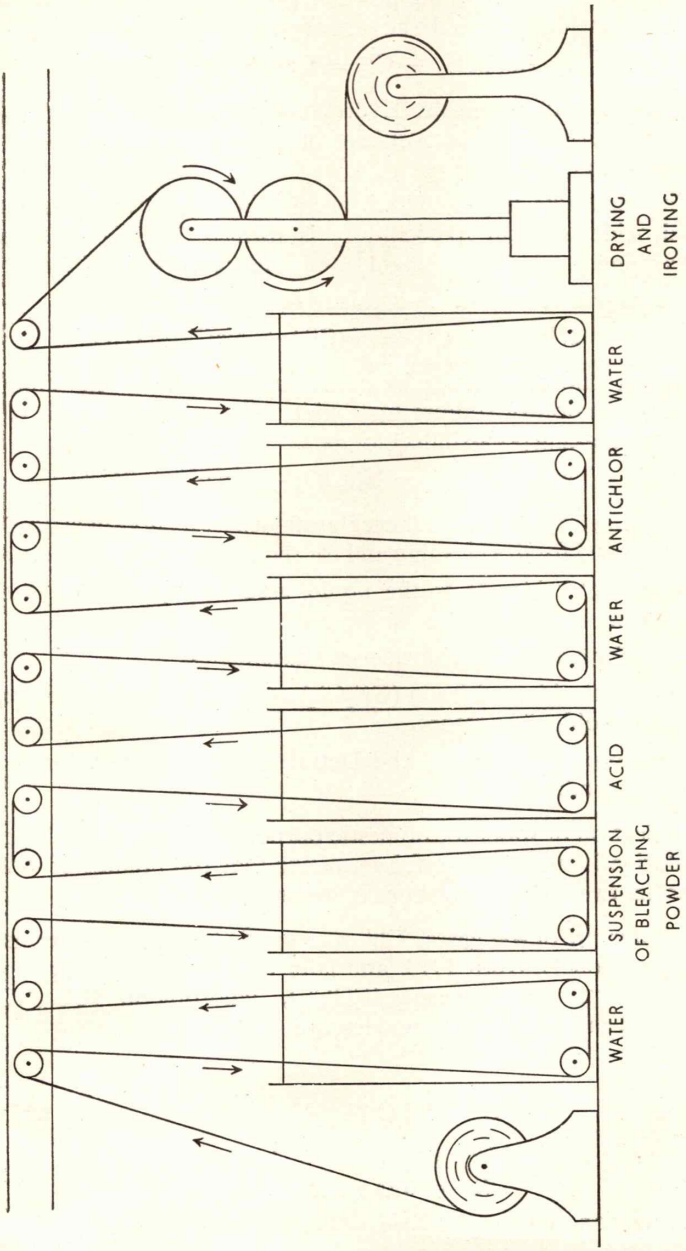

FIG. 35. Diagram of plant used for bleaching fabrics.

2. Manufacture of bleaching powder. Slaked lime is moved down a tower up which is forced a stream of chlorine.

$$Ca(OH)_2 + Cl_2 = CaOCl_2 + H_2O$$

3. Preparation of chemicals. Hydrochloric acid is prepared by burning hydrogen in an atmosphere of chlorine, and absorbing the product in water.

   When chlorine is passed into a cold dilute solution of sodium hydroxide, sodium hypochlorite is formed. This is used as a bleaching agent, disinfectant, and ink remover. 'Milton' and 'Chlorogene' are solutions of this compound.

$$2NaOH + Cl_2 = NaClO + NaCl + H_2O$$

   Sodium chlorate is made by passing chlorine into a hot concentrated solution of sodium hydroxide. It is used as a weed killer and for making potassium chlorate.

$$6NaOH + 3Cl_2 = NaClO_3 + 5NaCl + 3H_2O$$

   Carbon tetrachloride and trichlorethylene are non-inflammable liquids used for dry cleaning and for removing grease from metals.

   Carbon tetrachloride is the liquid used in 'Pyrene' fire extinguishers.

   Chloroform and ethyl chloride are anaesthetics.

   Methyl chloride and freon (CF_2Cl_2) are used in the cooling coils of household refrigerators.

   Gammexane (insecticide) and Dettol (antiseptic) are chlorinated coal tar products.

4. Purification of water for domestic purposes, swimming baths, etc. Chlorine is such a powerful germicide that 100 pounds of it will sterilize twenty million gallons of water.

5. Manufacture of war gases. Chlorine was first used by the Germans at Ypres on 22 April 1915, and later other chlorine compounds were used, viz. phosgene ($COCl_2$), chloropicrin (CCl_3NO_2) mustard gas [$(C_2H_4Cl)_2S$], and lewisite ($C_2H_2AsCl_3$).

REVISION NOTES

Hydrochloric Acid
(Hydrogen chloride)

OCCURRENCE

Gastric juice, containing 0·2 per cent of hydrochloric acid.

PREPARATION

Commercial

By the combustion of hydrogen in an atmosphere of chlorine, and absorbing the product in water.

Laboratory

By the action of sulphuric acid on sodium chloride.

$$NaCl + H_2SO_4 = NaHSO_4 + HCl$$

PROPERTIES

1. Hydrogen chloride is a colourless gas which fumes in air. It has a sharp irritating odour.
2. Slightly heavier than air. Commercial hydrochloric acid contains 32 per cent of the gas, and has a relative density of 1·16.
3. Extremely soluble in water. The solution is called hydrochloric acid.
4. Neither burns nor supports combustion.
5. The solution of the gas in water is a strong acid.

REACTIONS

1. It reacts with metals before lead in the replacement series, metallic oxides, hydroxides, and carbonates to form salts (chlorides).
2. It is readily oxidized to chlorine.

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$$

TESTS

1. Hydrogen chloride forms dense white fumes with ammonia.
2. Hydrochloric acid gives a white precipitate with silver nitrate.

USES

1. For cleaning metallic surfaces before soldering. Spirits of salts and muriatic acid are hydrochloric acid. 'Killed spirits' is hydrochloric acid which has been partly neutralized with zinc.
2. Aqua regia, which is a mixture of hydrochloric and nitric acids, will dissolve gold and platinum.

CHLORINE

OCCURRENCE

As chlorine is a very active element it does not occur in a free state.

Combined

1. Sodium chloride in sea water and rock salt.
2. Sylvine (KCl) and carnallite ($KCl.MgCl_2.6H_2O$) in Stassfurt deposits.

PREPARATION

Commercial

Electrolysis of brine. When an electric current is passed through brine, the salt is split up into chlorine, which is liberated, and sodium, which reacts with the water to form sodium hydroxide and hydrogen.

Laboratory

1. Oxidation of hydrochloric acid with manganese dioxide.

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$$

2. Action of an acid on bleaching powder.

$$CaOCl_2 + H_2SO_4 = CaSO_4 + H_2O + Cl_2$$

PROPERTIES

1. Greenish-yellow gas with a characteristic pungent odour. As it is readily liquefied, it is usually stored and transported in steel cylinders and tank wagons.
2. Two and a half times as heavy as air.
3. Soluble in water. The solution is called chlorine water.
4. Does not burn, but supports the combustion of some substances, e.g. hydrogen, phosphorus, taper, etc.
5. Bleaches moist litmus and most colouring matter by oxidation.

REACTIONS

1. Combines directly with most elements to form chlorides.

$$H_2 + Cl_2 = 2HCl \qquad 2P + 3Cl_2 = 2PCl_3$$

2. Has a powerful affinity for hydrogen and will remove it from many of its compounds.

$$2H_2O + 2Cl_2 = 4HCl + O_2$$

$$H_2S + Cl_2 = 2HCl + S$$

3. Reacts with slaked lime to form bleaching powder.

$$Ca(OH)_2 + Cl_2 = CaOCl_2 + H_2O$$

4. Liberates iodine from iodides.

$$2KI + Cl_2 = 2KCl + I_2$$

TESTS

1. Characteristic colour and smell.
2. Bleaching action.
3. Liberates iodine from potassium iodide.

USES

1. Bleaching agent.
2. Manufacture of bleaching powder.
3. Manufacture of chemicals, e.g. hydrochloric acid, etc.
4. Germicide. Destroys bacteria in domestic water, swimming pools, etc.

12

Relative Density
Principle of Archimedes
Flotation

A MOST USEFUL piece of information about any substance is its 'heaviness' compared with that of other substances. We know that lead is heavier than aluminium, and that water is heavier than kerosene; but vague facts such as these are of little practical use. Consequently, the 'heaviness' of a substance is defined as the weight of unit volume of it. In the Metric system it is the weight of one cubic centimetre of the substance; in British measures, it is the weight of one cubic foot. The resulting value is called '*density*'.

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$$

As one cubic centimetre of water weighs one gram, and one cubic foot of water weighs 62½ pounds, the density of water can be expressed as either one gram per cubic centimetre or 62½ pounds per cubic foot.

As you have learned in your earlier work, scientists prefer to work in one simple, universally-accepted system. Consequently, when they are referring to the 'heaviness' of a substance they tend to use the term '*relative density*' or '*specific gravity*', which is independent of the system of weights and measures used in the different countries.

By relative density we mean the density of a substance compared with the density of a standard substance, water. Thus, if the density of a substance is 125 lb per cu ft, it is simpler to say that its relative density is $\frac{125}{62\frac{1}{2}} = 2$. Note that relative density is not a unit; it is simply a number or a ratio. In every country, irrespective of their particular weights and measures, it will be known that this substance, for example, weighs twice as much as the same volume of water.

Relative density is the number of times a substance is as heavy as the same volume of water.

Water has a relative density of 1. When we say that lead has a relative density of 11·3 we mean that it weighs 11·3 times as much as the same volume of water.

It will be seen that in the metric system density and relative density are numerically the same.

Density of mercury = 13·6 g per cc
Relative density of mercury = 13·6

The relative density of a substance is determined by dividing the weight of a certain volume of the substance by the weight of the same volume of water.

$$\textit{Relative density} = \frac{\textit{Weight of substance}}{\textit{weight of same volume of water}}$$

Simple Methods of Finding Relative Density

A. SOLIDS

1. Weigh the solid.
2. Find its volume by the displacement method and calculate the weight of the water displaced. If the solid is regular, e.g. a cube, its volume can be obtained by measurement and calculation.

B. LIQUIDS

Method 1. Using a relative density bottle.

A relative density bottle has a well-fitting ground glass stopper through which is drilled a fine hole so that the bottle can be completely filled each time. It is a vessel with which we can take exactly the same quantity of different liquids. To find the relative density of a liquid we weigh this bottle full of the liquid, and then full of water. Subtraction of the weight of the bottle from each result gives the weights of an equal volume of the liquid and of water. The weight of this volume of liquid is then divided by the weight of the same volume of water.

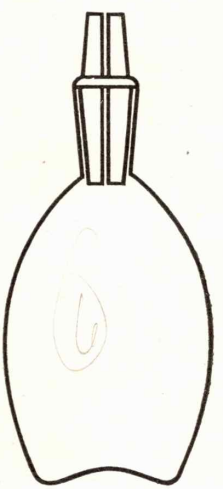

Fig. 36. A relative density bottle.

EXPERIMENT *To find the relative density of methylated spirits.*

1. Weigh a clean, dry relative density bottle.
2. Fill it with methylated spirits,* wipe dry, and weigh.
3. Return the spirits to its container, rinse out the bottle with water. Fill the bottle with water,* wipe dry, and weigh again.
4. Tabulate your work and calculate relative density as follows:

Weight of empty R.D. bottle	= g
Weight of bottle + methylated spirits	= g
Therefore weight of methylated spirits	= (S) g
Weight of bottle + water	= g
Therefore weight of water	=(W) g

$$\text{Relative density} = \frac{\textit{weight of a certain volume of liquid}}{\textit{weight of same volume of water}}$$

$$= \frac{S}{W}$$

$$=$$

Method 2. Using a burette.

A measured volume of the liquid is run out of a burette and weighed. Its relative density can then be calculated.

Other methods of determining relative density will be described later (see pages 140-142, and 145).

THE PRINCIPLE OF ARCHIMEDES

Most people know by experience that heavy objects are easier to move or lift under water than in the air. No doubt you have noticed that as you climb out of a swimming bath the greatest effort is called for just when your body is clear of the water; you feel heavier then. Get a brick, tie a piece of cord round it, and lower it into a bucket of water; notice how much lighter it feels when it is completely immersed. If you have a spring balance you can find out just how much weight seems to be lost when the brick is lowered into water.

EXPERIMENT *To study the apparent loss in weight of a body when it is immersed in a liquid.*

Suspend a small tin from a suitable spring balance and hold it in position so that it will collect the water which overflows from a eureka can (*Fig.* 37). Attach a glass stopper or similar object to another spring balance, and after you have recorded the readings on both balances, lower the

*Make certain there are no air bubbles below the stopper.

stopper into the water in the eureka can. Now note the new weights and then calculate the decrease in one case and the increase in the other. Repeat the experiment using other objects and other liquids, e.g. methylated spirits.

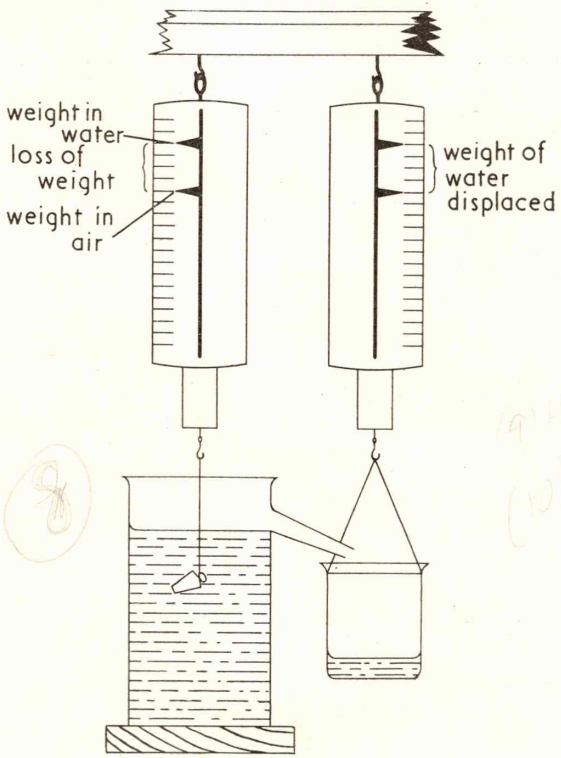

FIG. 37. Experiment to demonstrate the Principle of Archimedes.

In all cases it will be found that *when an object is weighed in air and then in a liquid, the loss in weight will be equal to the weight of the liquid displaced.* To Archimedes goes the credit of being the first to discover this law, which is known as the Principle of Archimedes.

HOW TO USE ARCHIMEDES' PRINCIPLE TO DETERMINE RELATIVE DENSITY

A. *Of a Solid*

As you know, a body wholly immersed in a liquid must displace its own volume of the liquid. It also appears to lose in weight, and

this loss in weight is equal to the weight of the liquid displaced. It will be clear, then, that Archimedes' Principle provides us with an easy and accurate method of finding the weight of an equal volume of water. As the experiment will give you both the weight of the solid and the weight of an equal volume of water, it will be a simple matter to calculate the relative density.

$$\textit{Relative density of solid} = \frac{\text{weight of solid}}{\text{weight of an equal volume of water}}$$

$$= \frac{\textit{weight of solid in air}}{\textit{loss of weight in water}}$$

EXPERIMENT *To determine the relative density of a solid.*

Attach a piece of thread to a small glass or metal object, and suspend it from a spring balance. Record its weight in air and its weight when immersed in water. Now calculate its relative density as follows:

Weight of solid in air	=	g
Weight of solid in water	=	g
Loss in weight Weight of water displaced Weight of an equal volume of water	=	g

$$\text{Relative density} = \frac{\textit{weight of solid in air}}{\textit{weight of an equal volume of water}}$$

B. *Of a Liquid*

If we lower a solid into a number of different liquids it will displace the same *volume* in all cases, and the apparent loss of weight each time will tell us just how much that same volume of each liquid *weighs.*

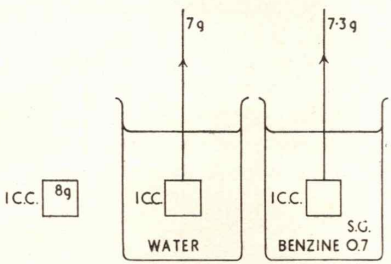

FIG. 38. Loss of weight in a liquid depends on the R.D. of the liquid.

Thus we can find the relative density of a liquid simply by comparing the loss of weight of a solid in that liquid with its loss of weight in water.

$$\textit{Relative density of liquid} = \frac{\textit{loss of weight in liquid}}{\textit{loss of weight in water}}$$

EXPERIMENT *To find the relative density of methylated spirits using Archimedes' Principle.*

Weigh a solid (as large as convenient) in air, in methylated spirits, and then in water. Tabulate your results as follows:

Weight of solid in air	=	g
Weight of solid in methylated spirits	=	g
Apparent loss of weight in methylated spirits	=	g
Weight of solid in water	=	g
Apparent loss of weight in water	=	g

$$\text{Relative density} = \frac{\textit{weight of substance}}{\textit{weight of equal volume of water}}$$

$$= \frac{\textit{loss of weight in liquid}}{\textit{loss of weight in water}}$$

$$=$$

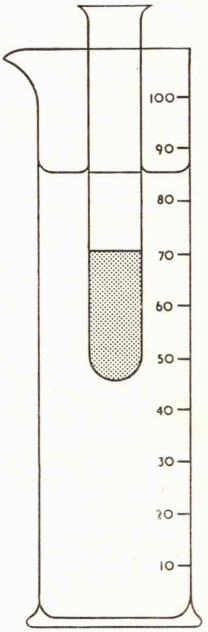

FIG. 39. Flotation.

FLOTATION

A lump of iron sinks to the bottom of a liquid, yet a great steel ship floats. Why is this?

EXPERIMENT *To demonstrate the law of floating bodies.*

Partly fill a test-tube with sand so that it will float upright. Weigh it. Fill a measuring cylinder with water up to the 70 cc mark. Carefully lower the test-tube into the measuring cylinder, and read the level to which the water rises: subtraction of the first reading will give the volume of water displaced. From this you can calculate the *weight* of the displaced water. How does it compare with the weight of the floating test-tube?

Add more sand to the test-tube and repeat the experiment. Tabulate your results as follows:

Weight of test-tube and sand	=	g
1st reading of measuring cylinder	=	cc
2nd reading of measuring cylinder	=	cc
Therefore, volume of water displaced	=	cc
Hence, weight of water displaced	=	g

It will be found that the weight of the water displaced by the floating test-tube is the same as the weight of the test-tube itself.

Law of Floating Bodies

A floating body displaces its own weight of the liquid in which it floats.

The test-tube in the above experiment sank until it had displaced its own weight of water, and this point was reached before it was completely submerged. A solid lump of iron sinks in water because it cannot possibly displace its own weight of this liquid. However, the same amount of iron, when fashioned into the shape of a ship, displaces its own weight of water when only partly immersed.

A block of ice 100 cubic feet in volume weighs approximately the same as 92 cubic feet of water: hence it will float with 8 cubic feet or roughly one-twelfth of its volume above the water. In salt water, which is denser than fresh water, about one-tenth of the volume of an iceberg is seen above the surface.

Can you explain why a drop of water will sink to the bottom of a tin of oil?

EXPERIMENT *The Cartesian diver.*

Take a small glass tube, such as is used as a container for propelling-pencil leads or lighter flints, partly fill it with water, and place it in a bottle* of water. When you put the cork in the bottle you will find that you can make the 'diver' sink to the bottom or rise to the surface simply by varying the pressure on the cork. As a matter of fact, it is possible to make the diver sink merely by pressing on the sides of the bottle with thumbs and fingers, but careful adjustment of cork and air space is necessary.

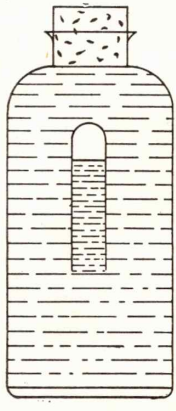

FIG. 40. The Cartesian Diver.

This model is an interesting illustration of the law of floating bodies. Pressure on the cork forces a little more water into the glass tube: it cannot then displace its own weight of water and therefore sinks.

PROBLEM *Which is the heavier?*

Figure 41 shows at *A* a eureka can filled with water. *B* is the same can with a block of wood floating in it. In both cases the water is level with the overflow spout. After you have reasoned it out, check your result experimentally.

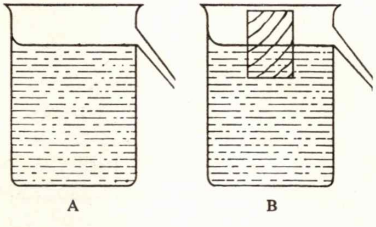

FIG. 41. Which is the heavier?

*An 8 oz medicine bottle is suitable.

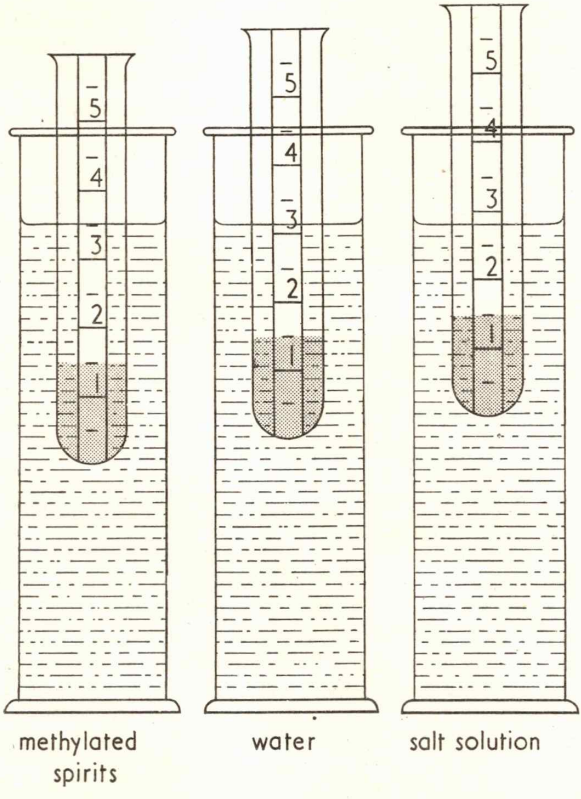

FIG. 42. A weighted test-tube floating in liquids.

APPLICATIONS OF THE LAW OF FLOATING BODIES

1. THE HYDROMETER

EXPERIMENT *To make a hydrometer.*

Place some sand in a test-tube to make it float upright. Fit a paper scale into the test-tube. You now have a simple hydrometer. Allow it to float in each of the following liquids: (1) methylated spirits, (2) water, (3) common salt solution, and note the depth to which it sinks in each case. Why does it sink to a greater depth in the methylated spirits than in the other liquids?

The Hydrometer is a floating instrument used for finding the relative density of liquids. It sinks into a liquid until it has displaced its own weight of the liquid, and hence the greater the density of the liquid, the higher it floats, just as a ship floats higher in salt water than in fresh water.

The hydrometer consists of three parts:

(i) The weight at the bottom, usually of mercury or lead shot, to make the instrument float upright.

(ii) The float, or air chamber, to provide buoyancy.

(iii) The stem, in which is placed the scale of densities. It is made long and narrow so that small differences in density make relatively large differences in depth of immersion.

The scale has the largest values at the bottom. It is not uniform, the larger values being closer together.

Hydrometers are usually supplied in sets of instruments, each covering a small range, since one instrument covering the full range would be inconveniently large. A typical set is: 0·7–1·0, 1·0–1·5, 1·5–2·0. It is quite usual to omit the decimal point on hydrometer scales, so that these instruments would be marked 700–1000, 1000–1500, and 1500–2000.

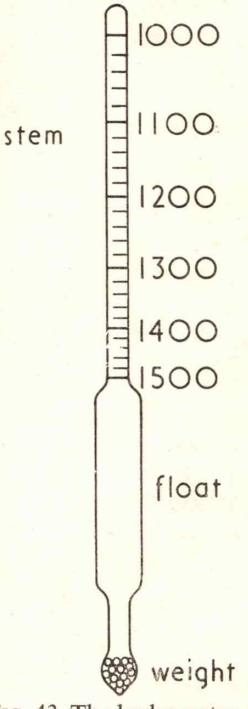

FIG. 43. The hydrometer.

Uses of the Hydrometer

(i) For testing the acid in car batteries. A very small hydrometer is enclosed in a glass syringe by means of which a sample of the acid is drawn from the battery. The acid in a fully-charged battery has a relative density of about 1·26, dropping to about 1·16 when it is discharged.

(ii) For testing milk. The instrument is called the *lactometer*, and is graduated from 15 to 40, since the range 1·015 to 1·040 is ample to cover any milk sample. Excessive water in the milk would lower its relative density, but removal of cream raises it, so if cream is removed and water added the relative density may not change.

(iii) For estimating the proportion of alcohol in wines and spirits.

2. The Plimsoll Line

Before the present century, ships were sometimes lost at sea because they were overloaded with little regard for the safety of the crews. Samuel Plimsoll persuaded Parliament to make it compulsory to put a safety mark on every ship. No ship may be loaded beyond this line.

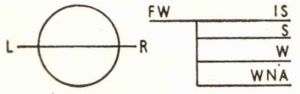

FIG. 44. The Plimsoll Line.

LR: Lloyd's Register
IS: Indian Ocean in summer
W: Winter
FW: Fresh water
S: Summer in temperate latitudes
WNA: Winter, North Atlantic

3. The Submarine

A submarine is provided with ballast tanks which are filled with air when the vessel is floating on the surface of the water. When certain valves are opened, water fills these tanks and increases the weight of the ship until it is greater than the weight of the water it displaces. The submarine therefore sinks below the surface, and, as it moves forward, its depth is controlled by horizontal fins. The ship will surface when the water is driven out of the ballast tanks by compressed air.

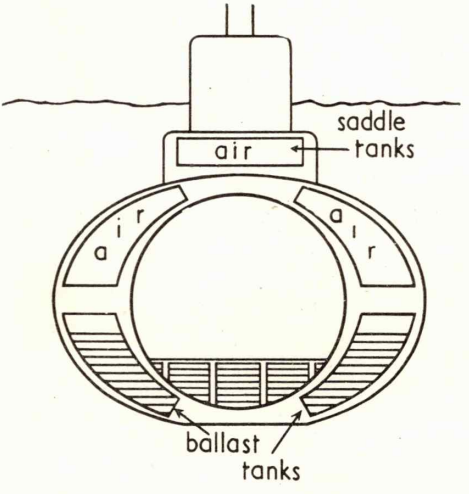

FIG. 45. A cross-section of a submarine.

4. BALLOONS

Balloons and airships provide a further illustration of the law of floating bodies. A balloon filled with hydrogen weighs very much less than an equal volume of air. A balloon therefore floats because it cannot displace its own weight of air. If it were set free it would continue to rise until the weight of the displaced air was the same as the weight of the balloon itself, provided the balloon did not burst.

SUMMARY

1. Relative density or specific gravity is the number of times a substance is as heavy as the same volume of water.

$$\textit{Relative density} = \frac{\textit{weight of substance}}{\textit{weight of same volume of water}}$$

2. Methods of determining relative density:
   i. By the direct method.
   ii. By using the specific gravity bottle.
   iii. By using the burette.
   iv. By means of the Principle of Archimedes.

$$\textit{Relative density of a solid} = \frac{\textit{weight of substance}}{\textit{loss of weight in water}}$$

$$\textit{Relative density of a liquid} = \frac{\textit{loss of weight in liquid}}{\textit{loss of weight in water}}$$

   v. By means of the hydrometer.

3. THE PRINCIPLE OF ARCHIMEDES: *When a body is weighed in air and then in a liquid, there is an apparent loss in weight. This apparent loss in weight is equal to the weight of the liquid displaced.*

4. THE LAW OF FLOATING BODIES: *A floating body displaces its own weight of the liquid (or gas) in which it floats.*

5. Illustrations of the law of floating bodies are:
   a. the hydrometer;
   b. the Plimsoll line, or safe loading line, for ships;
   c. the submarine;
   d. balloons and airships.

EXERCISE

1. Complete the following table:

No.	*Substance*	*Weight*	*Volume*	*Relative Density*
1	Iron	156 g	20 cc	
2	Brass	43 g	5 cc	
3	Sulphur	625 lb	5 cu ft	
4	Wood	475 lb	10 cu ft	
5	Mercury	g	3 cc	13·6
6	Magnesium	g	12 cc	1·7
7	Alcohol	lb	2 cu ft	0·8
8	Glass	lb	8 cu ft	3·0
9	Silver	105 g		10·5
10	Copper	106·8 g		8·9
11	Carbon	1000 lb		2·0
12	Zinc	875 lb		7·0

2. A relative density bottle weighed 10·5 g when empty and 35·5 g when filled with water. When filled with methylated spirits it weighed 31·5 g. What is the relative density of the methylated spirits? What would 1 gallon of methylated spirits weigh? [1 gal of water weighs 10 lb.]

3. A piece of glass weighs 55 g in air and 33 g in water. Find the relative density of glass. What will it weigh if totally immersed in a liquid of relative density 1·15?

4. A cube of metal of edge 2 cm weighs 48 g. Calculate the relative density of the metal. What will the cube weigh when completely immersed in (a) water, (b) methylated spirits (r.d. 0·8)?

5. A piece of metal of r.d. 7·5 weighs 45 g in air. What will it weigh when immersed in water? What is the r.d. of a liquid in which the metal weighs 36 g?

6. A solid weighing 161 g is found to weigh 138 g in water. Calculate its relative density.

7. A piece of brass weighs 127·5 g in air, 112·5 g in water, and 115·5 g in kerosene. What is the r.d. of kerosene?

8. A model boat is found to displace half a litre of water when it floats. What is its weight?

9. A rectangular solid measures 18 in long, 8 in wide, and 6 in deep. It weighs 31 lb. Will it float in water? (Density of water is 62½ lb per cu ft.)

10. A ship has a displacement of 2000 tons. Find the volume of fresh water it displaces. (Density of water is 62½ lb per cu ft.)

11. A wooden cube of edge 5 cm weighs 75 g. What is the smallest weight which must be added to hold it under water?

12. A barge is 30 ft long, 6 ft broad, and 4 ft deep. If it weighs 22,500 lb, how far will it sink in fresh water?

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Fluid Pressure: Pumps

Weight and Pressure

If you have ever tried walking through soft snow, you will know how tiring it is, and how slow is the progress made. This is because at every step you sink deeply into the snow. If you put on a pair of snowshoes or skis you will be able to proceed easily over the surface of the snow. The reason is that though your *weight* is the same, the *pressure* on the snow in the second case is very much less, for your weight is distributed over a much larger area.

Pressure is defined as the weight or force exerted on a unit of area. It may be measured in pounds per square inch, pounds per square foot, or grams per square centimetre.

$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

Pressure in Liquids

EXPERIMENT *To show that pressure in a liquid is transmitted equally in all directions.*

Make a hole in a rubber ball, and puncture it in a number of places. Fill it with water, and press down upon it. The water will squirt out in all directions, although the ball is pressed in one direction only.

EXPERIMENT *To show the effect of depth on pressure.*

Drill a series of holes up the sides of a tall metal tin, or use the apparatus shown in Figure 46. Fill it with water. Each jet of water emerges at right angles to the side of the tin. Notice also that the speed of a jet lower down is greater than that of one higher up, showing that pressure increases with depth.

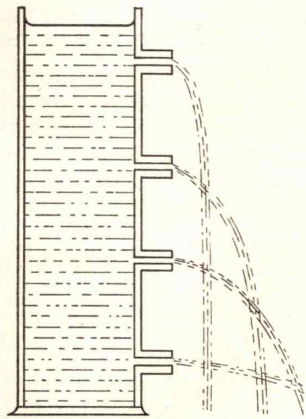


Fig. 46. Experiment to show the effect of depth on pressure.

EXPERIMENT *To show that a liquid exerts an upward pressure.*

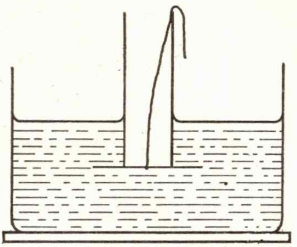


FIG. 47. Experiment to show that a liquid exerts an upward pressure.

1. Hold a cardboard disc against one end of a lamp glass by means of knotted thread, and lower it into a trough full of water.
2. Release the thread and note that the disc is held in position by the upward pressure of the water.
3. Pour water (preferably coloured with a little ink or potassium permanganate) into the lamp glass. Notice that the cardboard disc stays in position until the level inside just exceeds the level outside. This shows that the upward pressure exerted at any depth in a liquid is equal to the downward pressure exerted by the liquid at the same depth.

EXPERIMENT *To show that the pressure in a liquid at any point depends upon its depth and density.*

1. Connect the stem of the thistle funnel to one arm of the U-tube by means of rubber tubing. Partly fill the U-tube with water.
2. Fill the glass cylinder with water and lower the thistle funnel into it, as shown in Figure 48. It will be noticed that the water levels in the U-tube change; the greater the depth to which the thistle funnel is lowered, the greater the difference of levels in the U-tube.
3. Repeat the experiment, using methylated spirits in the glass cylinder. A similar result will be obtained, except that the difference in levels at any particular depth will be less than that produced by water.

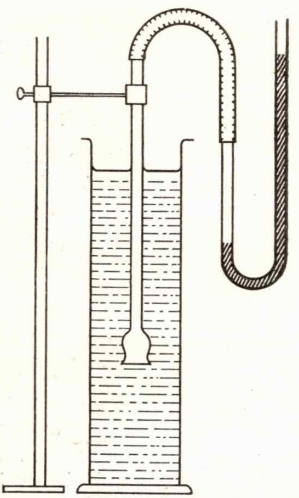
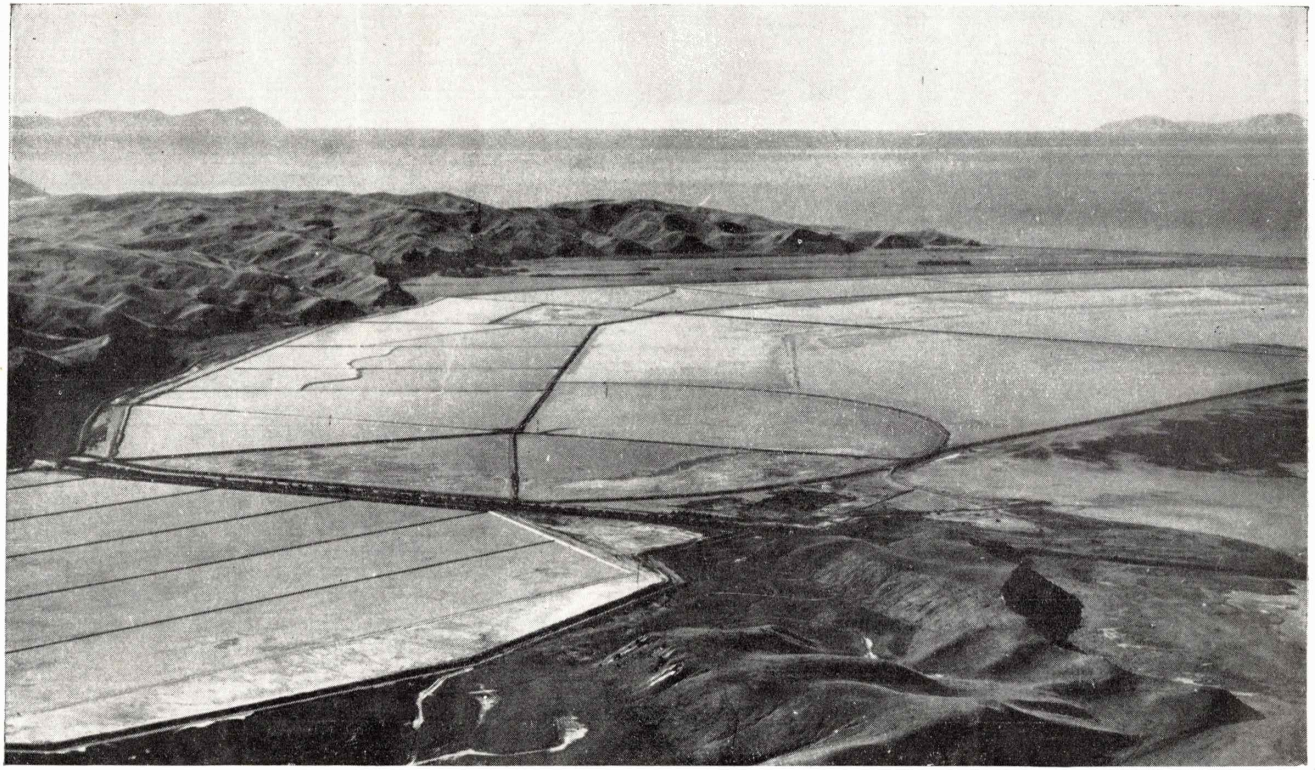


FIG. 48. Experiment to determine the pressure at a point in a liquid.

Thus we see that pressure in a liquid depends on its depth and density. The following illustrations should make this clear.

Imagine a column of water as in *Fig. 49.* One cubic foot of water weighs 62½ lb; 2 cubic feet of water weigh 125 lb; 3 cubic feet



V. C. BROWNE

7. Salt pans at Grassmere (Page 127)

DOMINION SALT LTD.

8. A salt-harvesting machine at work (Page 127)

weigh 187½ lb; 4 cubic feet weigh 250 lb. Hence the pressure at each depth will be:

62½ lb per sq ft at 1 ft	187½ lb per sq ft at 3 ft
125 lb per sq ft at 2 ft	250 lb per sq ft at 4 ft

Now suppose the liquid to be methylated spirit. 1 cu ft of methylated spirit weighs 51 lb, so it is obvious that the pressure at 1 ft depth is 51 lb per sq ft, at 2 ft it is 102 lb per sq ft, and at 4 ft, 204 lb per sq ft.

We have seen that pressure at any point in a liquid is the weight of a column of the liquid above one unit of area. It can be calculated by multiplying the depth in feet by the density in pounds per cubic foot. In the metric system the depth in centimetres should be multiplied by the density in grams per cubic centimetre.

The total force on the bottom of a vessel is found by multiplying the pressure on each square centimetre (or square foot) by the area.

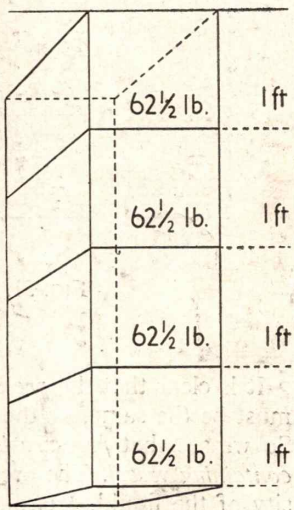


FIG. 49. Pressure in a liquid increases with depth.

If we repeat the last experiment, using a thistle funnel of shapes shown in *Fig. 50*, and covered with thin rubber sheet, we will get results similar to those already obtained. Thus, at a given depth, a liquid exerts the same pressure in all directions.

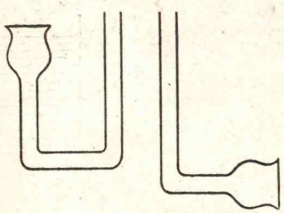


FIG. 50. Funnels used to show that a liquid exerts the same pressure in all directions.

COMMUNICATING VESSELS

You have no doubt heard the expression, 'Water finds its own level'. If several vessels of different shapes, as in *Fig. 51* (b), are connected together, and filled with water, it is found that if they are exposed to the same pressure, the levels are the same. In the teapot [*Fig. 51* (c)], the level in the spout is the same as that in the

teapot. Water-heating cisterns are provided with a glass tube outside to indicate the level of the water in the cistern [*Fig. 51* (a)].

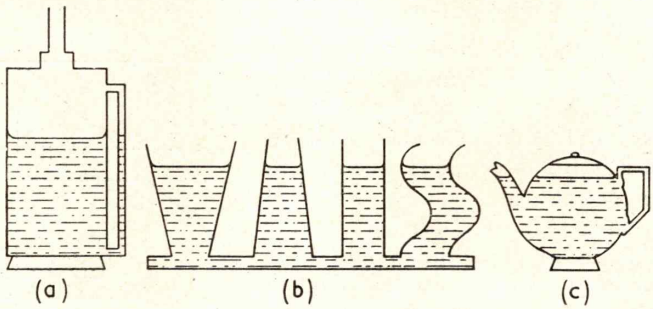


FIG. 51. Water finds its own level.

It is clear that the *pressure* in each of the communicating vessels must be the same, or the water would flow from one to the other. So we see that *pressure is independent of the shape and size of the containing vessel.* The pressure depends only on the depth and density of the liquid. Pascal, the French philosopher, was the first to demonstrate this.

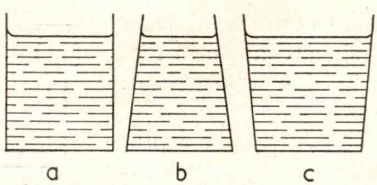
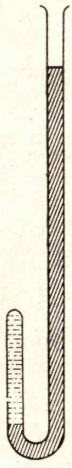


FIG. 52. Pressure on the bottom is independent of the shape of the containing vessel.

In *Fig. 52*, the vessels A, B, and C each have the same base area. Which has the greatest pressure on its base? The answer is that the pressure on the base of each is the same. The quantity and *weight* of water in A is greater than that in B, and less than that in C, but the pressure in each is the same, since it depends on the depth and density only.

The Effect of Pressure on Liquids

EXPERIMENT *To show the effect of pressure on liquids.*



1. Fill the short closed arm of the J-tube with water.
2. Stand the J-tube in a burette stand* and nearly fill the open arm with mercury. (A thistle funnel with a short stem drawn to a narrow opening is useful for pouring in the mercury.) It will be found that the lower level of the mercury remains in the same place. Hence we deduce that liquids are practically incompressible. The experiment may be repeated with several liquids.

FIG. 53. Experiment to show the effect of pressure on liquids.

Hydraulic Machinery

The characteristics of liquids—their incompressibility and the fact that they transmit pressure equally in all directions, are utilized in hydraulic machinery.

The hydraulic press consists of a narrow cylinder connected with a wide cylinder, both cylinders being fitted with pistons. It produces a large force from a small one but the force has to move through a much greater distance than the large one.

In *Fig. 54* a column having an area of cross-section of one square inch is connected to a column with a cross-section area of 10 square inches. A 10 lb weight on the narrow cylinder will support a 100 lb weight on the wide one. The pressure in both cases is 10 lb per square inch.

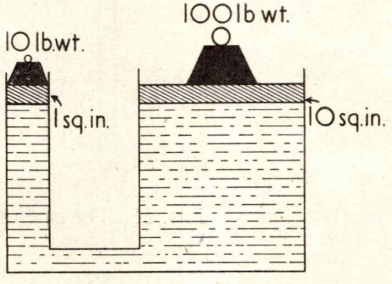


FIG. 54. The hydraulic press.

*Place this in a glass trough in case some mercury is spilt.

SUMMARY

1. Pressure is the force exerted on a unit of area.

$$Pressure = \frac{force}{area}$$

2. Pressure in a liquid is transmitted equally in all directions, and is exerted at right angles to any surface on which it is acting.
3. The pressure in a liquid increases with depth. The pressure at any point in a liquid depends upon
   a. depth,
   b. the density of the liquid.

   It is independent of the size and shape of the containing vessel.
4. Liquids are practically incompressible.
5. These characteristics of liquids make possible their use in hydraulic machinery.

MEASURING PRESSURE

The pressure of a gas may be measured by a pressure gauge or manometer. A simple gauge, in the form of an open-tube manometer, consists of a U-tube partly filled with water.

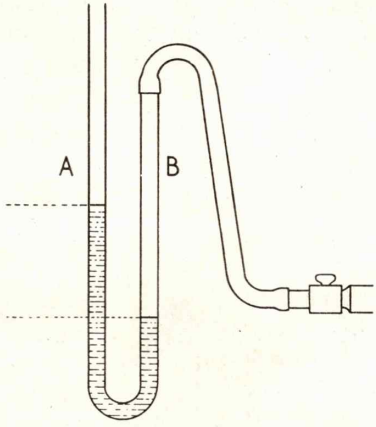


FIG. 55. The open-tube manometer.

EXPERIMENT *To measure the pressure of the coal gas in the gas main.*

Partly fill a glass U-tube with water, and by means of rubber tubing connect one arm to a gas-tap. Open the tap, and note the difference between the water levels in the two arms of the U-tube.

The pressure on the open arm A, *Fig. 55*, is that of the atmosphere; on the other arm, B, it is that of the gas in the main. The difference is therefore equal to the pressure of the column of water marked by the dotted lines.

The Bourdon Gauge

The Bourdon Gauge is in very common use for measuring the extremely high pressures of steam engines and gas cylinders. It is also used for measuring water pressure in fire engines, and oil pressure in cars and other machines.

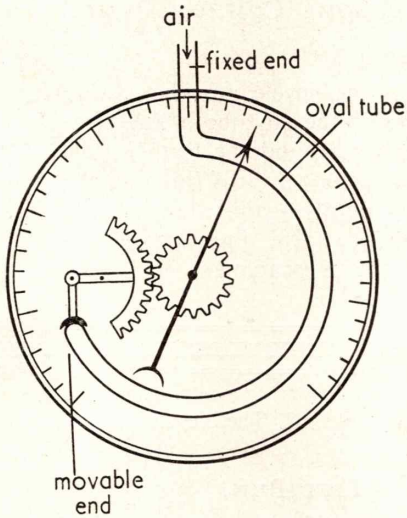


FIG. 56. The Bourdon pressure gauge.

This gauge consists of a flat or oval metal tube closed at one end, and bent into a circular shape. The open end admits the fluid under pressure, and the closed end is attached to a lever which moves the pointer by means of a gear-wheel. The pressure of the liquid or gas in the tube tends to straighten the tube, with consequent movement of the pointer.

The Tyre Gauge

Motor-car tyres are constructed to give their best service at certain specified pressures (usually 25 lb to the square inch). Hence a regular check should be kept on them by means of a tyre pressure gauge.

It consists of a rubber sac (A) held by a spring (B), contained in a metal cylinder. Air pressure in the rubber sac forces the graduated inner cylinder (C) up the tube. The pressure is read from the graduation mark just visible above the outer cylinder.

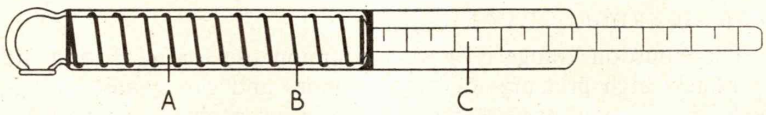


FIG. 57. A tyre pressure gauge.

SOME COMMON PUMPS

1. THE BICYCLE PUMP

Like other pumps, the bicycle pump has two valves, but one of these valves is placed inside the air-tube of the tyre. When the piston is withdrawn, air passes around the leather valve (*Fig. 58*). This air is now compressed by downwards force on the piston, pushing the leather of the valve tightly against the walls of the pump. It is thus forced through the tyre valve. Pressure on the rubber tubing of the tyre valve prevents the air escaping.

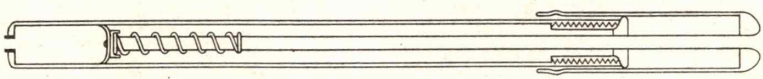


FIG. 58. The bicycle pump.

2. THE COMMON LIFT PUMP

The two valves of the lift pump are shown in *Fig. 59*.

Downward stroke of piston. This compresses the air below the piston, hence V 2 closes and V 1 opens.

Upward stroke of piston. The pressure below the piston decreases. Air pressure opens V 2 and closes V 1. Now as the piston moves up and down, it steadily exhausts the pipe of air and water is forced up the pipe by the pressure of the atmosphere. In due course the whole pipe and the pump are full of water. Then, with each upstroke the piston actually lifts the water above it to the spout. The lift pump is an *air* pump until it is full of water.

Air can support a column of mercury 30 inches high. Since mercury has a relative density of 13·6, you can see that it will support a column of water about 34 feet high. Hence we should expect the lift pump to be able to raise water 34 feet above the level of water in a well. In practice, however, imperfect valve seals limit the height to

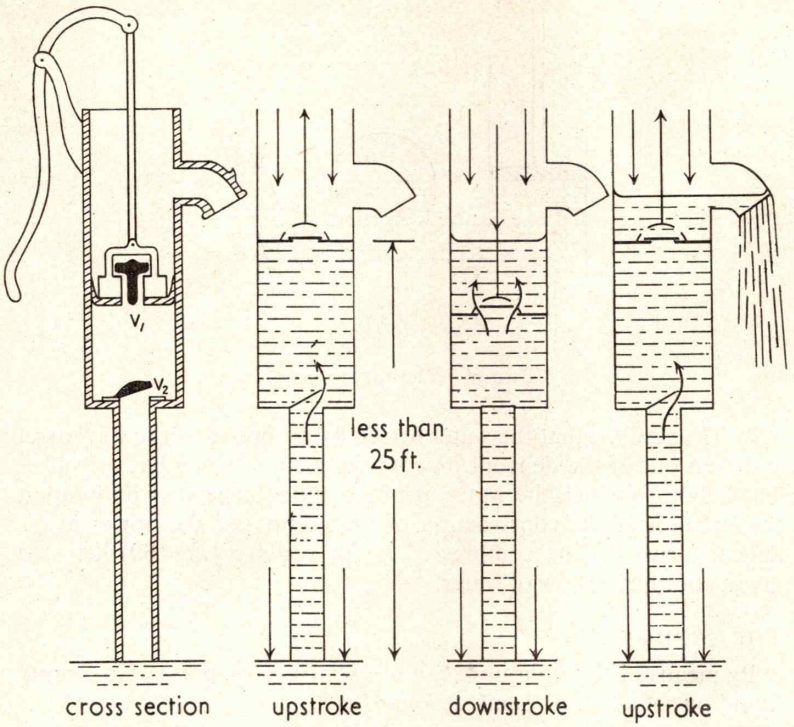


FIG. 59. The lift pump.

about 24 feet. Although the *piston* must not be more than 24 feet above the water level, the pump can raise water to a greater height, depending only on the efficiency of the valve V1, for it is this valve and the piston, and not the pressure of the atmosphere, that supports the water above it. The *up-stroke* of the piston is the work stroke.

Most lift pumps will not work unless some water is first poured into the barrel to make the valves seal more efficiently.

THE FORCE PUMP

By the force pump water may be raised to a greater height than is possible with the lift pump. The construction of the force pump is shown in *Fig. 60.*

When the piston is raised, the pressure in the barrel is decreased, causing V 1 to open and V 2 to close. Downward movement of the piston increases the pressure in the barrel, closing V 1 and opening

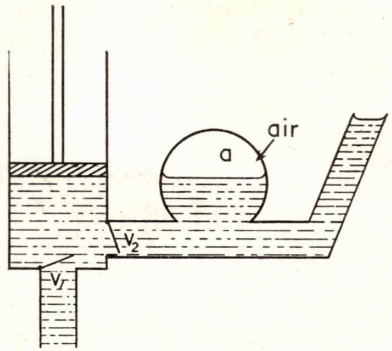


FIG. 60. The force pump.

V 2. The result is that the water forced by air pressure into the barrel is driven out of the delivery pipe by the piston, which has no valve. The height to which the water can be pumped depends wholly upon the strength of the construction of the pump and the power available to drive it. The compressed air in vessel *a* (*Fig. 60*) helps to give a continuous flow of water.

THE SIPHON

By means of the siphon we can use atmospheric pressure to empty liquid out of a vessel. Look at *Fig. 61.*

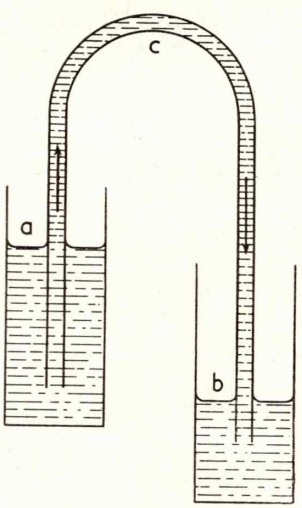


FIG. 61. The siphon.

The atmosphere presses equally upon the surfaces of the liquid in both vessels, *a* and *b*. But there is a higher column of water above *b* than above *a*. Consider *c*.

Pressure due to *a* = atmospheric pressure — column *ac*

Pressure due to *b* = atmospheric pressure — column *bc*

Therefore, pressure to right of *c* is less than that on the left and hence there is a flow in direction *acb*.

The siphon will not, of course, work through a height in excess of 34 ft, since air will not support a column of water higher than this.

You can easily make a model siphon by bending a piece of glass tubing and passing it through a cork to fit a bell jar, as shown in *Fig. 62*. As soon as the water reaches the top of the bend in the tube, the jar automatically empties.

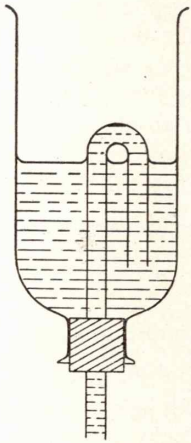


FIG. 62. A model siphon.

SUMMARY

1. The pressure of a gas may be measured by the manometer or pressure gauge.
2. Pumps, such as the bicycle pump, the lift pump, and the force pump, must have two valves. The height to which the lift pump and the force pump will raise water depends upon the strength of their construction and upon the efficiency of their valves. In practice, the piston in both must not be more than 24 ft above the level of the water to be raised.
3. In the siphon, air pressure is used to make liquid flow from a higher level to a lower.

14

Force, Work, Power, Energy, Velocity and Acceleration

FORCE, WORK, POWER

IN RIDING A BICYCLE we apply a force to the pedals to make the driving wheel turn; we also apply a force to the brakes to stop the machine. A tennis player applies a force with his racket to change the speed of the ball or the direction in which it is travelling. A motorist applies a force to the steering wheel to make the car turn round a corner. In a rugby football scrum both packs of forwards exert considerable force in an effort to push the opponents off the ball, but the scrum as a whole may not move. It does move if one side can produce a greater force than the other.

From the above examples we can see that force is something which tries to make an object—

(1) move, if it is stationary;

(2) stop moving, or move more quickly, if it is already in motion;

(3) change its direction, if it is moving.

It may not succeed in doing any of these things. It can do so only if it is of sufficient magnitude to overcome the resistance or force opposing it.

> *Force is that which changes or tends to change a body's state of rest, or uniform motion in a straight line.*

One of the units we may use to measure force is the pound weight, which is a measure of the earth's attraction on a mass of one pound. In the metric system we may use the gram weight.

When the force actually makes something move, we say that 'work' is done. You may apply all the force you can muster in an effort to unscrew the lid of a jar of fruit, but if it does not move you have done no work. Work is done, however, when the jar is lifted. The amount of work done is calculated by multiplying the force acting by the distance through which it acts, and is measured in units such as foot-pound, gram-centimetre, etc.

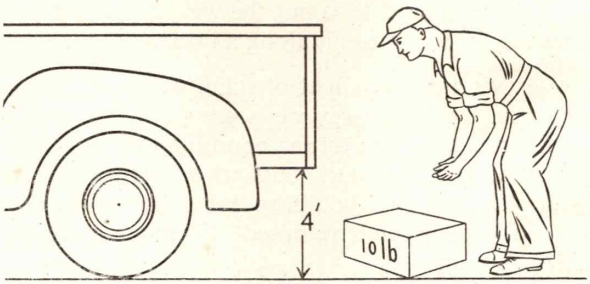


FIG. 63. Work done against gravity.

WORK (ft-lb) = FORCE (lb weight) × DISTANCE (feet)

or WORK (g-cm) = FORCE (g weight) × DISTANCE (cm)

The foot-pound may thus be defined as the work done in raising a mass of 1 lb through a vertical distance of 1 ft, or, as the work done when a force of 1 lb wt acts on an object through a distance of 1 ft.

In *Fig. 63* a man lifts a load of 10 lb through a vertical distance of 4 ft. The work he does is (10 lb × 4 ft) = 40 ft-lb.

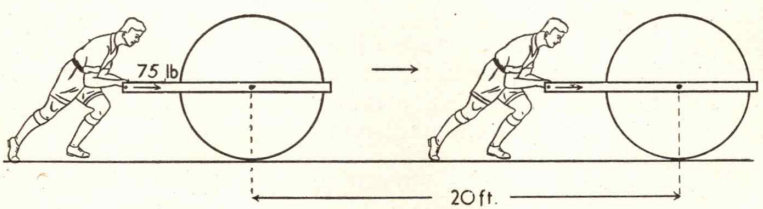


FIG. 64. The work done is the product of the force and the distance through which the force acts.

A certain roller (*Fig. 64*) will just move if a force of 75 lb is applied to it in a horizontal direction. What work is done by a boy who pushes it 20 ft along a plane surface?

Work = force × distance

= 75 lb × 20 ft

= *1500 ft-lb.*

NOTE: In this example 75 lb is not the weight of the roller; it is the force required to move it along a horizontal plane.

Even when we ascend a flight of stairs we are doing work in the scientific sense, for the energy we possess is being used to exert a force to raise our mass against the opposing force of gravity. If you weigh 10 stone and walk up stairs to a height 15 feet vertically above your starting point, you have done (140 × 15) or 2100 foot-pounds of work, since you have raised 140 pounds a vertical distance, of 15 feet, against gravity.

You may walk up slowly, or you may be in a hurry and run up. In the latter case you are clearly working at a greater *rate*. Rate of working is called *power*. If you walk up the stairs in one minute, you are working at the rate of 2100 ft-lb per minute; whereas running up in half a minute would be a rate of working of 4200 ft-lb per minute.

HORSE-POWER

You probably know that James Watt (1736-1819) manufactured steam-engines. Nobody was likely to replace horses with steam-engines unless he was convinced the steam-engines would do the same work more quickly. So Watt conducted experiments to determine the rate at which a draught horse could work. He set some horses the task of pulling a weight of 100 lb from the bottom of a deep well. As they could do this while walking at 2½ mph, he calculated that they did $366\frac{2}{3}$ ft-lb of work per second. To be on the safe side, however, he made allowances for the work of overcoming friction, and credited the horses with working at the rate of 550 ft-lb per second. This has ever since been taken as one horse-power—the unit for the rating of power of various engines.

$$1 \text{ horse-power} = 550 \text{ ft-lb per second,}$$
$$= 33{,}000 \text{ ft-lb per minute.}$$

To determine the rate of working, in horse-power, divide the total work done in one minute by 33,000; or the total work done in one second by 550.

EXAMPLE A crane raises 12 tons of coal a height of 25 feet in 2 min What is its rate of working?

$$\text{Load} = 12 \text{ tons}$$

$$= 26880 \text{ lb}$$

$$\text{Vertical distance moved} = 25 \text{ feet}$$

$$\text{Time taken} = 2 \text{ min}$$

$$\therefore \text{ Work done in 2 min} = 26880 \times 25 \text{ foot-pounds}$$

$$\therefore \text{ Work done in 1 min} = \frac{26880 \times 25}{2} \text{ foot-pounds}$$

$$\therefore \text{ Rate of working} = \frac{26880 \times 25}{2 \times 33000} \text{ horse-power}$$

$$= \frac{112}{11} \text{ HP}$$

$$= 10\tfrac{2}{11} \text{ HP.}$$

ENERGY

Energy is defined as 'the capacity for doing work'. To do work, we must exert a force. Thus we see that the exertion of a force and the doing of any work depend on a supply of energy being available. We have already learned that most energy comes, directly or indirectly, from the sun.

Potential Energy

Many substances can release energy during a chemical change. When coal burns, for example, heat energy is produced, and this heat energy in turn can be transformed into other forms of energy. A dry battery uses its chemical energy to produce electrical energy, which may be converted into heat or light. Anything which can move from a high level to a lower level by the force of gravity acting on it possesses energy simply by virtue of its *position*, e.g. the water in high-level lakes. The energy stored up in a body, or possessed by it because of its position, is known as *potential energy*.

Kinetic Energy

Once a body begins moving, it possesses an energy which would keep it going indefinitely were it not for the forces opposing it. This is *kinetic* energy, the energy of *motion*. If water (having potential

energy) is allowed to flow downhill, the *kinetic* energy of its movement can be used to drive turbines which will generate electric power. A cricket ball can possess far more energy than that due to its own weight, a fact you will appreciate if you have caught a 'hard one'.

The forces which oppose the motion of a body are chiefly (1) air resistance, and (2) friction.

Whenever an object moves over another object, it is opposed by a resistance which we call *friction*. The result is another form of energy—heat. In all machinery friction not only can cause excessive wear of moving parts but can waste a considerable amount of energy. Motor-car engines carry oil, which is pumped under pressure to all moving parts. Loss of this oil would result in serious damage to the engine.

A 'high' finish for all metal-to-metal surfaces, the use of roller bearings, and adequate lubrication are the principal means of reducing friction in machines.

Conservation of Energy

We have seen that one form of energy can be transformed into another form. Thus the chemical energy of burning coal produces the heat, which, in a steam turbine, is changed into *motion* to drive an electric dynamo. The electrical energy, in turn, may be transformed into heat energy, light energy, or the energy of motion. But though some of this energy might be wasted, it is never lost. All the electrical energy supplied to a lamp is not converted into light. Much of it is wasted in the form of heat. *Energy can be neither created nor destroyed: it can only be converted into other forms of energy.* This is known as the Principle of the Conservation of Energy.

SUMMARY

Force is that which changes, or tends to change a body's state of rest or uniform motion in a straight line.

A unit of force is the pound weight (British system). In the metric system it is the gram weight.

Work is done when the application of a force results in the *movement* of a body.

$$Work = force \times distance$$

The unit of work in the British System is the foot-pound.

Power is the rate of doing work. It may be calculated in foot-pounds per minute.

1 horse-power = 550 ft-lb per second
= 33,000 ft-lb per minute

Energy is the capacity for doing work.

Potential energy is the energy stored in some substances, or possessed by them by virtue of their *position* or state.

Kinetic energy is the energy of motion.

The principle of the Conservation of Energy: Energy can be neither created nor destroyed.

MOTION : VELOCITY AND ACCELERATION

When a man is driving a motor-car he keeps an eye on the speedometer to see that the speed at which he is travelling is within the limits set by law. As you know, the speed must not exceed 30 miles per hour in a built-up area, or 50 miles per hour on the open road. By speed, we mean the distance travelled in a unit of time, e.g. 30 miles per hour, or 44 feet per second. It is the rate of motion at a particular instant.

Suppose a person drives a car from Wellington to Auckland. His speed at any particular time will vary greatly; it may be 50 mph on a long straight road, and drop to as low as 5 mph in other places, as in passing a mob of sheep. His *average speed* is calculated by dividing the total distance travelled by the time taken over the whole journey. If he makes this journey, a distance of 420 miles, in 15 hours, his average speed is $\frac{420}{15} = 28$ mph.

$$Average\ speed = \frac{distance}{time}$$

Velocity includes another factor—that of direction. Velocity is speed in a particular direction. A car travelling at a uniform speed along a straight road may be said to be moving at a uniform or constant velocity. More often than not, however, its velocity is changing both in amount and direction. When the engine is supplied with more petrol the vehicle *accelerates*. *Acceleration* means the increase in velocity in a given time.

Suppose a car is moving due north along a straight track at 15 miles per hour (22 feet per second) and in 8 seconds reaches a speed of 45 miles per hour (66 feet per second). The increase in velocity is clearly (66 — 22) or 44 feet per second, but this increase takes 8 seconds to accomplish. The change in *velocity per second* is therefore $\frac{44\ feet\ per\ second}{8\ seconds}$ or 5½ feet per second per second. The acceleration in this example is therefore 5½ feet per second per second.

$$Acceleration = \frac{increase\ in\ velocity}{time}$$

Acceleration Due to Gravity

Drop a penny and a penny stamp to the floor from the same height. Which reaches the floor first? Now try again: this time place the stamp flat on top of the penny before letting them drop. They fall together. Why?

Until the time of Galileo (1564-1642) it was believed that the speed at which bodies fall to the ground was in direct proportion to their weight. Galileo thought otherwise, and to prove his contention performed an experiment which has become famous. You have no doubt seen pictures of the Leaning Tower of Pisa. From the highest possible ledge of this tower, Galileo dropped a 100-lb weight and a ½-lb weight together. They fell together and reached the earth apparently together. Galileo's experiment is of profound importance, not only for what it demonstrated but because it marked the beginning of a new approach in scientific method—that of carrying out experiments to test a theory and to establish a law.

Later, Sir Isaac Newton performed an experiment with a guinea and a feather, in which he allowed them to fall in a vacuum. He proved that they fell at exactly the same speed. If it were not for the resistance of the air all bodies, whatever their weight, would fall to the ground at the same speed.

Galileo next turned his attention to the problem of discovering how far a body would fall in a given time, and by how much its velocity increased as it fell. If a body fell a certain distance in one second, would it fall just twice that distance in two seconds? How would its velocity at the end of two seconds compare with its velocity after falling one second? Would it be twice as great?

Experiments carried out by Galileo gave the answers to all these questions. Acceleration due to gravity (usually denoted by the letter g) is 32 feet per second per second. A falling body has a uniform acceleration. At the end of the first second its velocity is 32 feet per second. After two seconds its velocity is 64 feet per second. In three seconds its velocity is $64 + 32 = 96$ feet per second, and so on.

Terminal Velocity

A body falling in air does not continue to accelerate indefinitely. At the point where air resistance becomes so great as to be equal to the weight of the falling body, acceleration ceases. The body is said to have reached its *terminal velocity*.

'The terminal velocity of a man falling through air without a parachute is about 120 miles per hour; with a parachute it is equal to that acquired by jumping from a 13 ft wall, i.e. about 20 mph'.

—*McKenzie*

SUMMARY

Speed is the distance travelled in a unit of time.

$$\textit{Average speed} = \frac{\textit{distance}}{\textit{time}}$$

Velocity is speed in a particular direction.

$$\textit{Acceleration} = \frac{\textit{increase in velocity}}{\textit{time}}$$

Acceleration due to gravity (g) = 32 ft per sec per sec.

The acceleration of a falling body is uniform. In practice it is affected by the resistance of the air.

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Moments : Levers : Pulleys

MOMENTS OF FORCES

A SMALL BOY can balance a larger boy on a see-saw provided he sits further away from the centre than the larger boy. As you will know from your own experience, the first thing two children do when they sit on a see-saw is to shuffle backwards and forwards until they feel well balanced. Would it be possible to eliminate this trial-and-error method, and find some simple means of determining where each should sit so that one would not upset the balance? The following experiment should point the way.

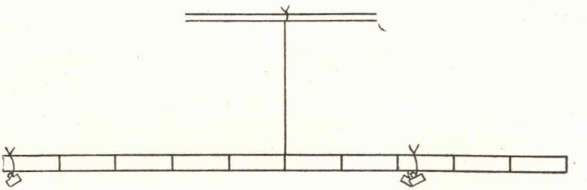


FIG. 65. Balancing a rod with two different weights.

EXPERIMENT *To study the principle of the see-saw.*

Tie a loop of cotton round the middle of a metre scale and suspend it from a retort stand. Move the scale through the cotton loop until it balances.

1. Tie loops of cotton to a 20 g weight, and two 20 g weights (40 g).
2. Suspend the 20 g weight near one end of the scale. Now find where a (a) 20 g, (b) 40 g weight has to be suspended from the other arm in order to balance the scale.
   Carefully measure the distance of each weight from the point of balance.
3. Repeat the experiment, using instead of the 40 g weight, weights of 60 g, 80 g, and 100 g. In each case make a careful record of the distances of the weights from the point of balance.
   The point about which the scale turns, which we have referred to as the 'point of balance', is called the *fulcrum*.

Tabulate your results as follows:

	LEFT SIDE			RIGHT SIDE		
	(*1*) *Force*	(*2*) *Distance from fulcrum*	(*1*) × (*2*)	(*1*) *Force*	(*2*) *Distance from fulcrum*	(*1*) × (*2*)
1.	20 g			20 g		
2.	20 g			40 g		
3.	20 g			60 g		
4.	20 g			80 g		
5.	20 g			100 g		

In each case multiply the force by its distance from the fulcrum.

What do you notice? If you have made your measurements carefully, you will find that in each case the product of the force and its distance from the fulcrum on the right-hand side is the same as it is on the left-hand side.

We call a rigid rod or bar, such as the see-saw and that used in the above experiment, a *lever*. When any such rod or lever is supported at a point, each side or arm has a tendency to turn, due to the force of gravity. This turning effect of a force is called the *moment* of the force. Forces, as you have already learned, are measured in pounds weight, or grams weight, and the moment of a force is found by multiplying the force by the perpendicular distance from the point about which the moment is required.

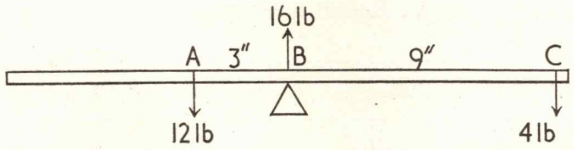


FIG. 66. A rod in a state of balance.

Consider the rod shown in *Fig. 66*. Here there are three forces at work—A, B, and C. The rod does not topple over because the turning tendency of the force at A is exactly balanced by the turning tendency of the force at C. In other words, the anti-clockwise moment of the force at A is the same as the clockwise moment of the force at C.

Anti-clockwise moment (A) = 12 × 3 = 36 lb-in

Clockwise moment (C) = 4 × 9 = 36 lb-in

Since the rod is supported at B there must be an upwards force at this point of 16 lb: were this not so, the rod would not remain where it is.

An important fact is that when any rod is in a state of balance, the anti-clockwise and clockwise moments about any point are equal. Let us return to the rod shown in *Fig. 66*. We may calculate the moments about each of the points at which forces are acting.

	Anti-clockwise	*Clockwise*
Moments about A	B 16 × 3 = 48 lb-in	C 4 × 12 = 48 lb-in
Moments about B . . .	A 12 × 3 = 36 lb-in	C 4 × 9 = 36 lb-in
Moments about C . . .	A 12 × 12 = 144 lb-in	B 16 × 9 = 144 lb-in

You will notice that in every instance the balancing moments are the same, and must always be so where we have a rod or lever in a state of balance. This is known as the Principle of Moments, which may be stated thus:

> *When a rod or lever is in equilibrium under the action of a number of forces, the sum of the clockwise moments taken about any point is equal to the sum of the anti-clockwise moments.*

EXPERIMENT *To verify the Principle of Moments.*

Support a metre rule at its mid-point. Hang two weights on the left side, and balance them by means of two weights suspended at different points on the right side; for example, use 100 g and 10 g on left, 50 g and 20 g on right side. Carefully measure distances of each weight from the fulcrum.

Tabulate results as shown. Repeat the experiment, using other combinations of weights.

LEFT-HAND SIDE			RIGHT-HAND SIDE		
Anti-clockwise moments			*Clockwise moments*		
Force	Distance from fulcrum	Moment	Force	Distance from fulcrum	Moment

Sum of moments: ..... Sum of moments: .....

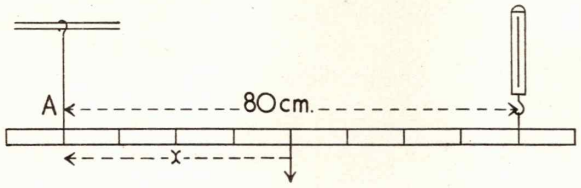


FIG. 67. Experiment to determine the point at which the weight of a rod acts.

EXPERIMENT *To determine the point at which the weight of a rod acts.*

1. Weigh a metre ruler.
2. By means of a piece of cotton, suspend the metre ruler from a stand at a point 10 cm from one end (*Fig. 67*).
3. Using cotton, attach it to a spring balance 10 cm from the other end.
4. Take the moments about point *A* to calculate the position of the point at which the weight of the ruler acts.

Set your results out as follows:

Weight of ruler = 0·2 lb
Reading of spring balance = 0·1 lb

Taking moments about *A*

Clockwise moments = anti-clockwise moments
$0{\cdot}2 \times x = 0{\cdot}1 \times 80$
$x = 40$ cm.

We conclude from this experiment that the weight of the rod acts at its mid-point, i.e. at its centre of gravity.

EXPERIMENT *To find the weight of a metre rule, using a 200 gram weight.*

Suspend the 200 gram weight from the end of the metre rule. Now find the point of balance of the rule. The choice of a fulcrum should present little difficulty: a triangular block of wood is suitable.

We learned from the last experiment that the weight of the rule acts at its centre of gravity, i.e. at its mid-point. The moment of this force is therefore the weight of the rule multiplied by the distance between the fulcrum and the mid-point.

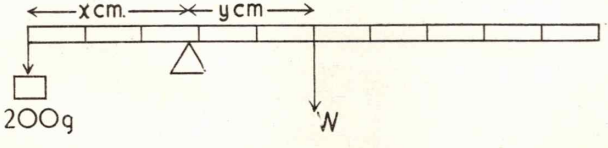


FIG. 68. Experiment to find the weight of a metre rule.

200 g × distance from fulcrum = weight of beam × distance from fulcrum to mid-point

Take moments about fulcrum, Figure 68

clockwise moments = anti-clockwise moments

$W \times y$ g cm = $200 \times x$ g cm

The values of x and y are read from the metre rule.

The value of W is then a simple calculation.

EXPERIMENT *To determine the pressure on the supports at the ends of a beam.*

Arrange a metre rule as indicated in Figure 69. It is supported near its ends by spring balances. The weight of the rule is 0·2 lb, and a weight of 0·8 lb is suspended from a point 20 cm from *A*. Calculate both clockwise and anti-clockwise moments first about *A*, and then about *B*.

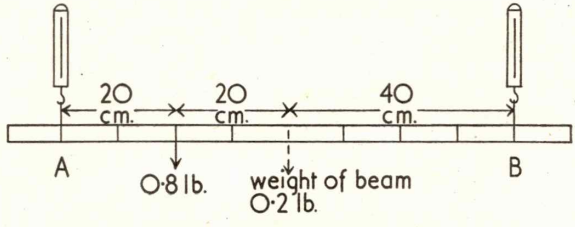


FIG. 69. Experiment to determine the pressure on the supports at the end of a beam.

1. Taking moments about *A*.

Anti-clockwise moments = clockwise moments

$80\ B = (0{\cdot}8 \times 20) + (0{\cdot}2 \times 40)$ lb cm

$80\ B = 16 + 8$ lb cm

$= 24$ lb cm

Therefore $B = \frac{24}{80} = 0{\cdot}3$ *lb.*

2. Taking moments about *B*.

Clockwise moments = anti-clockwise moments

$80\ A = (0{\cdot}8 \times 60) + (0{\cdot}2 \times 40)$ lb cm

$80\ A = 48 + 8$ lb cm

$= 56$ lb cm

Therefore $A = \frac{56}{80} = 0{\cdot}7$ *lb.*

NOTE The sum of the upward forces exactly equals the sum of the downward forces. Hence in the above experiment it is necessary to calculate about one point of support only: having determined the pressure on the support at one end, subtract this from the total downward forces to find the pressure on the support at the other end. You can then calculate the moments about the other end as a check.

In the above experiment actual results have been given to help you. It is not intended that you should perform an experiment which has been already worked out in advance: you should use a different weight to hang from the beam at some other point.

EXERCISE

1. A uniform rod 50 cm long balances at its mid-point.
   (*a*) If a 100 g weight hangs from one end, how far from the fulcrum must a 500 g weight be placed to keep the rod horizontal?
   (*b*) If a 100 g weight hangs from one end, what weight must be placed 10 cm from the other end to make the rod balance?
2. A boy weighing 5 stone sits 6 feet and a girl weighing 4 stone sits 4 feet from the fulcrum of a see-saw. Both are on the same side. Where must a man weighing 10 stone sit to make the see-saw balance?
3. A uniform metre rule has a mass of 150 g and is pivoted at the 60 cm graduation. It remains horizontal when a stone is suspended from the 90 cm mark. What is the mass of the stone?
4. A see-saw 12 feet long weighs 30 lb and is pivoted at a point 4 feet from one end. It balances when a man weighing 160 lb sits at the end 4 feet from the fulcrum and a boy sits at the other end. Calculate the boy's weight.
5. A uniform bar *XY*, 4 feet long and of mass 5 lb, is pivoted at *X*. It carries a load of 10 lb at *Y* and is maintained in a horizontal position by a spring balance attached to point *Z* on the bar 1 ft from *X*. Calculate the reading on the spring balance.

LEVERS

Any apparatus which enables us to magnify a force or to apply it more conveniently is called a machine. The lever is one of the simplest machines. The extent to which it magnifies the force applied depends upon the length of the arm available. If you cannot loosen a very tight nut with a short spanner you try again with a longer spanner. Now, the number of times a machine magnifies or increases the force applied is called its *mechanical advantage*. In *Fig. 70*, for instance, you see a simple lever in which an 'effort' of 40 lb-wt supports a 'load' of 200 lb-wt. It is able to do this because the 'effort arm' is five times as long as the 'load arm'. The mechanical advantage obtained is 5.

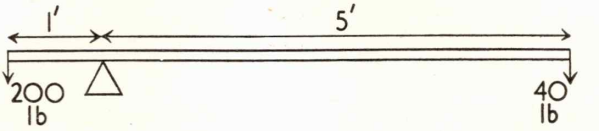


FIG. 70. This lever has a mechanical advantage of 5.

$$\textit{Mechanical advantage} = \frac{\textit{load}}{\textit{effort}} = \frac{W}{P}$$

$$= \frac{\textit{effort arm}}{\textit{load arm}}$$

A machine does not give us a mechanical advantage for nothing. It is often said, 'what is gained in force is lost in speed'. In the above example where the mechanical advantage is 5, the effort would have to move 5 inches in order to raise the load one inch; in other words, the ratio of the velocities of the load and effort is 5.

$$\textit{Velocity ratio} = \frac{\textit{distance moved by effort}}{\textit{distance moved by load}}$$

A high mechanical advantage can be obtained if there is a high velocity ratio. For example, in bottom gear of a car the velocity ratio is high; so also is the mechanical advantage. But for friction, these two ratios would be numerically the same.

CLASSIFICATION OF LEVERS

Levers are usually classified according to the relative positions of the load (W), the effort (P), and the fulcrum (F). The fulcrum must be either between the load and the effort, as in Class 1, or at one end of the lever as in Classes 2 and 3.

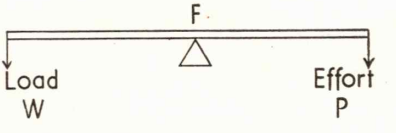


FIG. 71. Lever, Class 1: The see-saw type.

Class 1. The see-saw type

The fulcrum is placed between the load and the effort. The closer the load to the fulcrum, the higher the mechanical advantage obtained.

Examples: The beam of a balance, the steel-yard, scissors, pliers, claw-hammer.

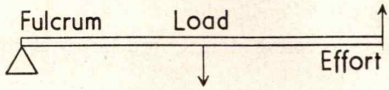


FIG. 72. Lever, Class 2: The wheelbarrow type.

Class 2. The wheel-barrow type

The load is placed between the effort and the fulcrum. Mechanical advantage must always be greater than 1.

Examples: Nutcrackers, bottle-opener, the oar of a boat.

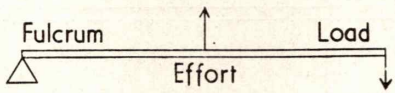


FIG. 73: Lever, Class 3: The forearm type.

Class 3. The fore-arm type

The effort is closer to the fulcrum than the load. Hence the mechanical advantage is always less than 1.

Examples: A pair of tongs, steam-engine safety valve.

PULLEYS

Pulleys are a very useful form of simple machine. If you wanted to raise a heavy object to some height, the pulley would enable you to do so while still standing on the ground and also provide you with a high mechanical advantage. Have a look at the big cranes on the waterfront and on ships, and you will see pulleys being used to great advantage.

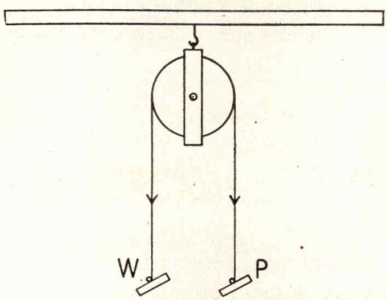


FIG. 74. A single fixed pulley.

EXPERIMENT 1 *A single fixed pulley.*

1. Support a rod on two retort stands, and tie or clamp a single pulley to it.

2. Pass a thread round the pulley and attach a ¼-lb weight to each end.

3. Add a ¼-lb weight to one end of the thread.

You will notice that the ¼-lb weights just balance each other, and that if a small weight is added to the 'effort' *P*, it moves downwards and raises the load *W*.

A single fixed pulley changes the direction of a force. If there were no friction at the pulley, the mechanical advantage would be 1.

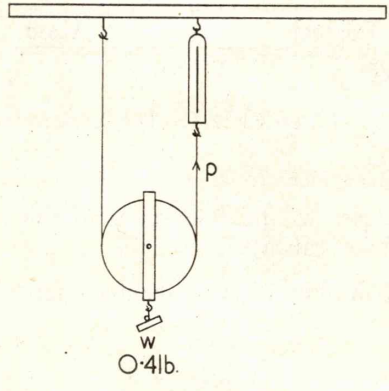


FIG. 75. A single movable pulley

EXPERIMENT 2 *A single movable pulley.*

1. Weigh the pulley.

2 Attach one end of a thread to a horizontal bar, pass it round a movable pulley, and fasten the other end to a spring balance which is also fixed to the horizontal support. The threads must be parallel.

3. Attach a 0·4 lb weight to the pulley and note the reading of the spring balance.

Note that the reading of the spring balance is one half of the total weight of the pulley and the load W. It is clear that the pulley with load attached is supported by two threads, each one supporting one half of the load.

A little more force applied at P would raise the load W, so that this arrangement has a mechanical advantage of 2 if we ignore loss due to friction.

A more convenient arrangement is a combination of a single movable pulley with a single fixed pulley.

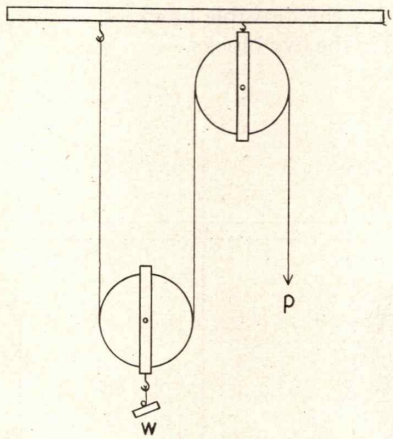


FIG. 76. A movable pulley with a fixed pulley.

The single fixed pulley is useful in changing the direction of the effort. The load is still divided between the two strings and the tension in the string is the same throughout, so this system still has a theoretical mechanical advantage of 2.

EXPERIMENT 3 Set up the above apparatus and use metre rulers to measure the distance moved by the load and by the effort.

It will be found that the effort moves twice as far as the load. This is expressed when we say that the velocity ratio is 2.

In a perfect machine the mechanical advantage and the velocity ratio would be the same.

EXPERIMENT 4 *Pulley blocks.*

Weigh a double pulley block and make it up to 2 lb with additional weights. Use this as the lower block and pass string around the pulleys as shown in Figure 77. Now find what weight must be attached to the free end of the string so that no movement takes place.

Use metre rulers to measure the distances moved by the load and the effort.

You will find that ½ lb or a little more will suffice to balance the load of 2 lb. The load W is supported by four strings, so that each

string supports one quarter of it. The effort required to support the load is thus one quarter of the total load (ignoring friction). The mechanical advantage in this case is 4, and is equal to the number of strings supporting the movable block. It is also equal to the total number of pulleys in the two blocks.

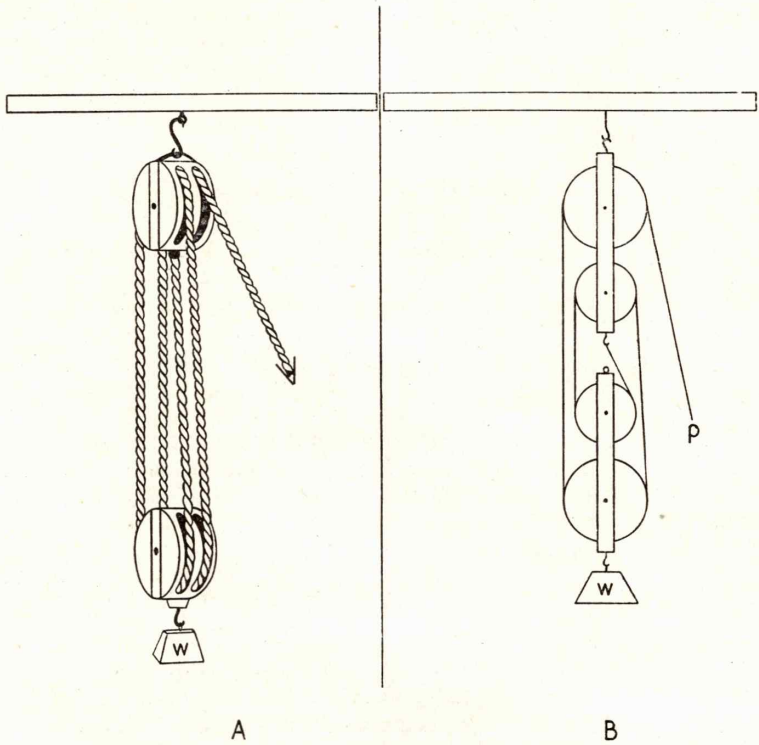


FIG. 77. Pulley blocks. B is the diagrammatic representation of A.

In order to raise the load the effort must move through four times the distance it moves the load. Suppose each of the four supporting strings is shortened by one inch: then 4 inches of string would have to be hauled in by the effort.

If we again ignore friction, the mechanical advantage and velocity ratio of these machines are numerically the same.

SUMMARY

System	*Mechanical Advantage*	*Velocity Ratio*
Single fixed pulley	1	1
Single movable pulley	2	2
Single fixed + single movable pulleys	2	2
Pulley blocks	= no. of strings supporting movable block, *or* total no. of pulleys in both blocks	

In practice, pulleys are well oiled to reduce the friction loss.

The Principle of Work

Nowhere do we ever get anything for nothing. We have seen that a machine can enable us to move, say, a 100-lb weight with a force of 20 lb. But the force has to move five times the distance it moves the load. This general principle is known as the Principle of Work: 'No machine can give out more work than is put into it'. If friction is neglected, *work done on load = work done by effort.*
In all cases, levers and pulleys included,

load × *distance moved by load* = *effort* × *distance moved by effort*

Efficiency

If, in fact, the above equation held true in practice, the machine would be perfect. But since no machine can be built that eliminates friction completely, there is no such thing as a perfect machine. In other words, no machine is one hundred per cent *efficient*. The efficiency of a railway engine, for instance, is regarded as good if it is 15 per cent, much of the energy supplied by the coal being wasted.

$$\textit{Efficiency} = \frac{\textit{work got out}}{\textit{work put in}} \text{ or } \frac{\textit{work done on load}}{\textit{work done by effort}}$$

This is usually expressed as a percentage.

Relation between Mechanical Advantage, Velocity Ratio, and Efficiency

Let load $= W$ lb-wt

effort $= P$ lb-wt

distance load moves $= b$ feet

distance effort moves $= a$ feet.

Then, work done on load $= W \times b$

and work done by effort $= P \times a$

$$\text{Efficiency} = \frac{W \times b}{P \times a} \ (\times 100)$$

$$= \frac{W}{P} \times \frac{b}{a}$$

$$= \frac{W}{P} \div \frac{a}{b}$$

$$\text{Now mechanical advantage} = \frac{W}{P}$$

$$\text{and velocity ratio} = \frac{a}{b}$$

$$\text{Hence, efficiency} = \frac{\textit{mechanical advantage}}{\textit{velocity ratio}}$$

SUMMARY

1. The tendency of a force to turn a rod or lever about the point at which it is pivoted is called the *moment* of the force.
2. The moment is calculated by multiplying the force by the perpendicular distance of the line of action of the force from the point about which it is acting.
3. When a body is in equilibrium under the action of a number of forces, the sum of the clockwise moments about any point is equal to the sum of the anti-clockwise moments. This is generally known as the *Principle of Moments*.
4. When a lever is in equilibrium, the total upward forces are equal to the total downward forces.

5. *Mechanical advantage* $= \dfrac{load}{effort}$

Velocity ratio $= \dfrac{distance\ moved\ by\ effort}{distance\ moved\ by\ load}$

6. The centre of gravity of a body is the point at which the whole of the weight of the body may be deemed to act.

7. *The Principle of Work.* No machine can give out more work than is put into it. If friction is neglected, work done on load = work done by effort. Load × distance moved by load = effort × distance moved by effort. This applies to all machines, of which the lever and the pulley are simple examples.

8. *Efficiency* $= \dfrac{work\ got\ out}{work\ put\ in} = \dfrac{work\ done\ on\ load}{work\ done\ by\ effort}$

16

Electric Cells and Circuits

THE FIRST person to succeed in obtaining a continuous current of electricity was Volta, who, about 1800, made his now famous 'pile'. This consisted of a large number of discs of copper and zinc piled on top of one another alternately, and separated by discs of leather. When this pile was wetted with salt solution and touched at top and bottom simultaneously by Volta he received an electric shock. Later, he improved on this pile by placing a copper plate and a zinc plate in each of a number of glass vessels fllled with dilute acid, and connecting the copper of one to the zinc of the next. The free copper plate at one end and the free zinc plate at the other end were the terminals of the battery. (A battery is a collection of cells.)

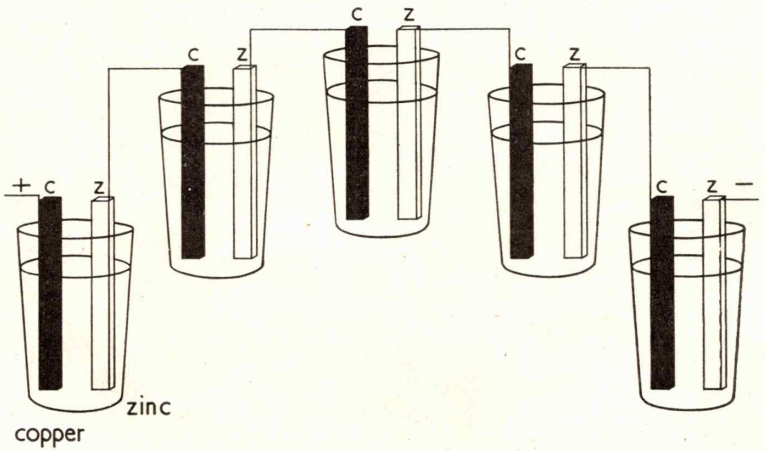


FIG. 78. Volta's battery.

PRIMARY CELLS

EXPERIMENT *To make a simple cell.*

It consists of plates of copper and zinc immersed in dilute sulphuric acid. Attach a copper wire to a zinc plate and another to a

copper plate,* and connect these wires to a torch lamp. Lower the plates into a beaker containing dilute sulphuric acid. The plates must not touch (*Fig. 79*). When the lamp ceases to glow, remove the plates and wipe the copper plate free of bubbles. This will make the cell work again. Finally, disconnect the lamp and you will see that bubbles keep on coming off the zinc plate.

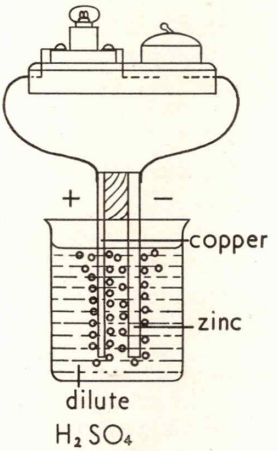


FIG. 79. A simple primary or Voltaic cell.

NOTE: The conventional current is said to flow from the copper called the *positive* plate, to the zinc or *negative* plate. We now know that the electron flow is in the reverse direction, but we still keep to the old conception as most of our electrical rules are based on it.

The lamp glows quite brightly at first, but soon grows dim and then goes out altogether. This is due to the formation of a covering of bubbles over the copper plate. The cell made in this experiment could not last long, as the zinc and acid continue to react until one or the other is completely used up, even when the cell is not in use.

REQUIREMENTS FOR A SIMPLE CELL

1. Two unlike conducting plates.
2. A conducting liquid (called the *electrolyte*).

**Note for teacher:* This is most conveniently done by screwing suitably-sized sheets of zinc and copper to a thin strip of wood so that they can be placed in a 150 cc beaker. Care should be taken that the screws from the copper plate do not touch the screws from the zinc plate.

The conventional current passing through the external circuit is always from the uneaten to the eaten plate. Various different pairs of substances can be chosen to form a simple cell when placed in a solution of an acid, alkali, or salt. In the section on chemistry you will learn something of the 'electro-chemical' or 'replacement' series —in which the metals are arranged in the order of their activity (see pages 94-97).

The further apart the two metals in this list, the higher is the voltage given by the cell. For practical purposes, however, many metals are not suitable, or too expensive.

The Defects of a Simple Cell

1. *Local action.* The negative plate goes on reacting with the electrolyte, even when the cell is not in use. This is overcome if the zinc plate, before being placed in the acid, is rubbed with mercury to form an amalgam which protects the impure zinc beneath it from the action of the acid.

2. *Polarization.* The positive plate soon becomes covered with hydrogen bubbles, which stop the action of the cell. It would be most inconvenient to wipe the plate every few minutes. To overcome this difficulty, an oxidizing agent is used—a substance which will combine with the hydrogen to form water. In one type of cell, potassium dichromate is used for this purpose.

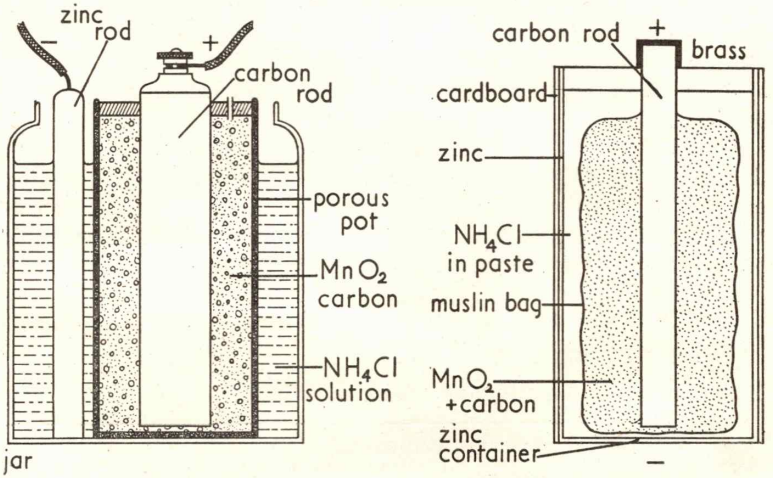


Fig. 80. A Leclanché cell and a dry cell.

The copper-zinc cell has an E.M.F.* of about one volt. Various cells have been devised to minimize the defects of the simple cell, the most commonly used being the Leclanché cell and its dry form, the ordinary torch cell.

The Leclanché cell has for its positive plate a carbon rod set in a porous pot containing manganese dioxide and powdered carbon. The manganese dioxide, an oxidizing agent, is the depolarizer; the powdered carbon is to provide better conductivity through the cell. The negative plate is a rod of zinc. The 'exciting liquid' or electrolyte is a solution of sal-ammoniac (ammonium chloride).

This cell requires very little attention, beyond the occasional addition of water to make good the evaporation losses.

The chemical change taking place in the Leclanché cell is given in the following equation:

$$Zn + 2NH_4Cl = ZnCl_2 + 2NH_3 + H_2$$

The hydrogen is oxidized to water by the manganese dioxide. The Leclanché cell gives an electrical pressure of rather less than 1½ volts.

The dry cell is a most useful and convenient form of the Leclanché cell. It is dry insofar as it cannot spill; if it were really dry inside it could not work. Let us compare the dry cell with its forerunner, the Leclanché cell.

EXPERIMENT Cut a used torch cell in half with a hack-saw and examine its contents. In the dry cell the negative plate is the zinc container. The positive carbon rod has a brass cap clipped on the top to make a good contact, while the manganese dioxide and powdered carbon are held around it in a muslin bag. The space between the carbon and the zinc container is occupied by the electrolyte—a paste of sal ammoniac and glycerine or starch. This is prevented from leaking out by a seal of pitch at the top of the cell.

The dry cell has an E.M.F. somewhat higher than the wet Leclanché cell, since there is no porous pot to reduce the current flow. Moreover, the zinc container completely surrounds the carbon rod. We usually express this by saying that the dry cell has less internal resistance than the Leclanché cell.

Dry cells are intended for intermittent work only. As in all primary cells, polarization is not completely overcome. The manganese dioxide cannot do its work fast enough to remove all the hydrogen formed. Hence the cell must be used for short periods only. Its great advantage lies in its portability, and batteries of dry cells are used for a wide variety of portable equipment, e.g. portable radios. Unfortunately, they deteriorate with age.

*Electro-motive force.

Each dry cell has an electrical pressure of 1½ volts, although when new the voltage may be as high as 1¾. Its size makes no difference to its voltage, but a big cell will give current at the same pressure for longer, and will last longer as it has more materials to use up.

Batteries are made by connecting cells in series (see p. 195), the zinc of one to the carbon of the next. The pressure obtained is equal to 1½ volts × number of cells.

Secondary Cells

The Lead Accumulator

The lead accumulator, or storage battery, is the kind of battery used in motor cars. It does not store electricity, but generates electricity in the same way as the simple primary cell does—by chemical change. It stores chemical energy. It differs from the dry cell in two important respects:

1. It can be recharged (a dry cell lasts only so long as its materials are not used up).

2. It has a low internal resistance. That is, it conducts electricity very well, permitting the flow of a large current. Dry cells could not give sufficient current to turn the starter motor of a motor car unless they were inconveniently large.

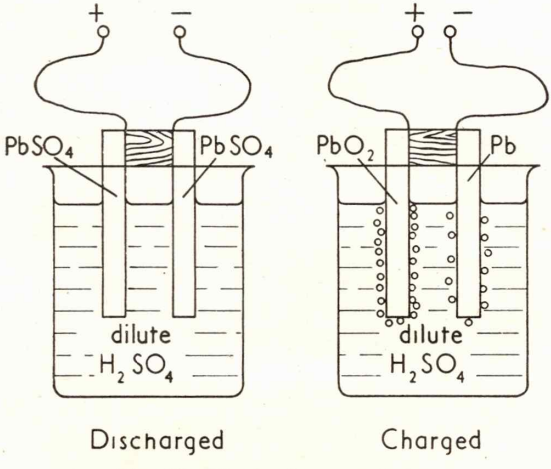


Fig 81. The lead accumulator.

Both dry cells and lead accumulators produce electricity, then, by chemical action. When a dry cell gives no more current it must be thrown away, but in the case of a lead accumulator we can use an electric current to reverse the chemical action and restore the plates to their original state.

EXPERIMENT *To make a lead accumulator.*

Cut two lead strips 3 in by 1 in and screw them to a wooden strip. A copper wire should be clamped in contact with each lead plate. Lower the pair of lead plates into a 150 cc beaker containing dilute sulphuric acid. Connect the plates to the terminals of a 6-volt accumulator and leave for several minutes. Note the bubbling and any colour changes in the plates. Disconnect the plates from the charging source, and connect them to a 2·5 volt torch bulb, or an electric bell.

You will notice that bubbles rise from the plates, and that the lead plate connected to the positive terminal of the accumulator gradually changes to a chocolate brown colour, while that connected to the negative terminal has a grey appearance. Your little lead cell gives a much brighter light than the simple primary cell.

More will be learned later (see page 207) about the changes that occur when an electric current passes through an electrolyte or conducting liquid. It will be sufficient here if the following changes are known:

1. *On first charging*

   Positive. The lead plate becomes coated with brown lead peroxide (PbO_2).

   Negative. 'Spongy' grey lead formed; hydrogen is evolved.

2. *On discharging*

   Both plates become coated with lead sulphate ($PbSO_4$).

   The acid loses strength. (The sulphate radical has combined with the lead.)

3. *On charging*

   Positive. Lead peroxide again formed.

   Negative. Lead again formed. The acid regains its strength, having recovered the SO_4 from the plates.

   The E.M.F. of the lead cell is 2 volts.

Remember that both the simple primary cell and the lead accumulator cell consist of two different substances immersed in a conducting liquid. They are compared in this table:

	Simple Primary Cell	*Dry Cell*	*Lead Accumulator*
Positive plate	Copper (Cu)	Carbon	Lead peroxide (PbO_2)
Negative plate	Zinc (Zn)	Zinc	Lead (Pb)
Electrolyte	Dil. sulphuric acid	Sal ammoniac	Dil sulphuric acid
Depolarizer	None	Manganese dioxide	None required
E.M.F. (volts)	1	1·5	2·0

As the lead accumulator discharges, the sulphuric acid in the solution is used to form lead sulphate on the plates. Thus the sulphuric

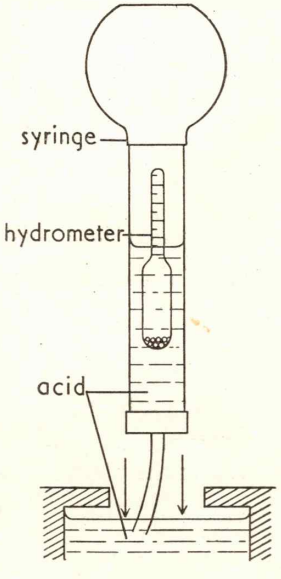


FIG. 82. Testing an accumulator by means of a hydrometer.

acid becomes weaker and consequently has a lower density. Hence we can determine the state of charge of an accumulator with the aid of a hydrometer (see *Fig. 82*).

A sample of the acid is drawn out of each cell by means of a large 'syringe' containing a small hydrometer in its glass tube. If a low relative density is shown we know that the acid is very dilute, and hence that the cell is in need of charging. The acid in a commercial accumulator when fully charged has a relative density of 1·25; discharged, 1·15. The positive terminal is usually painted red or marked +.

It will be obvious that only direct current (see p. 243) can be used for charging. The alternating current of the power supply has to be 'rectified' before it can be used for this purpose.

The capacity of an accumulator is rated in 'ampere-hours'. For example, a battery with a capacity of 60 ampere-hours will give a current of 1 ampere for 60 hours, ½ ampere for 120 hours, and so on. (It will not give a current of 60 amps for 1 hour, however!) The maximum rate of discharge is approximately 10 per cent of its capacity, i.e. do not draw off more than 6 amps from a 60 ampere-hour battery.

Care of an Accumulator

1. Keep it clean and dry, especially at the terminals.
2. Inspect the level of the acid regularly, and keep it above the plates by adding *distilled water*. If part of the plates is allowed to become dry, it becomes covered with an insoluble sulphate and that part of the plate ceases to function.
3. Do not leave it discharged for any time.
4. Avoid short circuits. Excessive rate of discharge may ruin the plates.

The commercial accumulator consists of sets of lead plates kept apart by separators. The larger the plates and the larger their numbers, the greater the capacity of the battery. Vast numbers of accumulators are manufactured annually.*

SUMMARY

1. The first battery was made by Volta about the year 1800.
2. In the electric cell, chemical energy is converted into electrical energy.

*'About £1 million worth of accumulators are being produced in New Zealand by less than 350 employees engaged in the storage battery industry. The annual over-all demand is for approximately 260,000 batteries of which, New Zealand produces about 247,000.'—*N.Z. Electrical Journal*, 25 July 1955.

3. The simple primary cell consists of two different metals immersed in a conducting liquid called the electrolyte, e.g. plates of zinc and copper in dilute sulphuric acid.
4. The defects of the primary cell are:
   (a) local action,
   (b) polarization.
5. The dry cell is a development of the Leclanché cell. It is 'dry' inasmuch as its contents do not spill.
6. The lead accumulator consists of plates of lead peroxide and of lead placed in sulphuric acid. It can be repeatedly recharged, and has the additional advantage of being able to supply heavy currents.
7. Cells are connected together to form batteries. (See also p. 201.)

ELECTRICAL UNITS

Electrical Pressure

You have already learned something of the nature of an electric current: it is a flow of electrons. Now, water will not flow through a pipe, nor will wind blow, unless there is a difference of pressure between one point and another. Similarly, there must be a difference of *electrical pressure* in a conductor in order to set the electrons in motion. We call this difference of pressure between two points a *potential difference.* In the experiment on page 191 a dry cell is used to create this pressure difference. A dynamo could equally well be used. The pressure difference set up by these sources of electricity is called an electromotive force (E.M.F.). Electrical pressure is measured by a voltmeter which is calibrated in volts.

Electric Current

The current that is made to flow through any conductor by the electrical pressure applied is measured in *amperes.* It would be possible to measure it in the number of electrons passing along a conductor each second, but the electron is such a tiny quantity of electricity that this would be most inconvenient. So we use a much larger quantity of electricity called the *coulomb* (about six million million million electrons) and measure the current flowing in coulombs per second. The word ampere stands for 'coulombs per second'. Current is a rate of flow. It is measured by an *ammeter.*

Resistance

Everything electricity flows through offers resistance to it. Copper, you have learned, is a good conductor because it offers only a low resistance. Resistance is measured in *ohms.* The resistance of one

bar of your electric radiator is about 53 ohms; of the 60-watt lamp in your room, about 880 ohms. Resistance depends not only on the substance conducting the electricity. The thinner the wire the greater its resistance; the longer the wire the greater the resistance. The resistance of metallic conductors increases with the temperature.

Summarizing our facts at this point, we may state that

(1) An electric current is a flow of electrons; rate of flow is measured in *amperes.*

(2) The flow of electrons from one point to another occurs when there is a difference of potential energy between those points. This potential difference (p.d.) is measured in *volts.*

(3) The *resistance* offered by substances to the flow of electrons is measured in *ohms.*

Relation between Units of Measurement

A potential difference of 1 volt will cause a current of 1 ampere to flow through a resistance of 1 ohm.

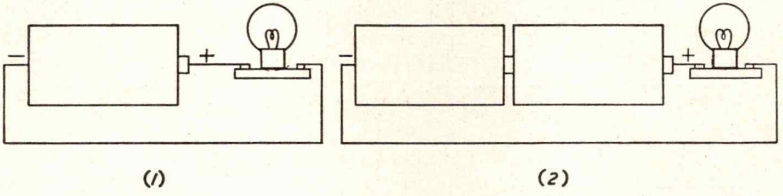


FIG. 83. Effect of doubling the potential difference.

EXPERIMENT *Effect of doubling the potential difference.*

1. Connect one dry cell to a torch bulb.
2. Connect two dry cells in series with the torch bulb as shown in *Fig. 83.* By connecting two cells in series we double the potential difference (E.M.F.), see page 190. Notice how much more brightly the bulb lights up when we do this.

EXPERIMENT *Effect of doubling the resistance.*

1. Connect one dry cell to one torch bulb.
2. Connect one dry cell and two torch bulbs in series as shown in Fig. 84.

By connecting two bulbs in series we double the resistance in the circuit. We are, of course, assuming that the resistance of each bulb is the same. Notice that the bulbs now glow very feebly, if they light up at all. Sometimes it is found that when the two bulbs are connected in this way, one bulb glows while the other shows no sign

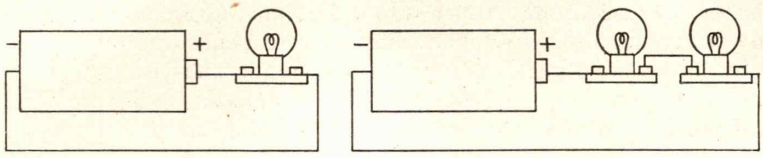


FIG. 84. Effect of doubling the resistance.

of light. In this case the bulbs are *not* of the same resistance, and you could try the experiment again, using two cells in series.

EXPERIMENT Repeat the two previous experiments, this time using meters to measure the potential difference and current flow in each case. Figures 85a and 85b show you how to connect the meters.

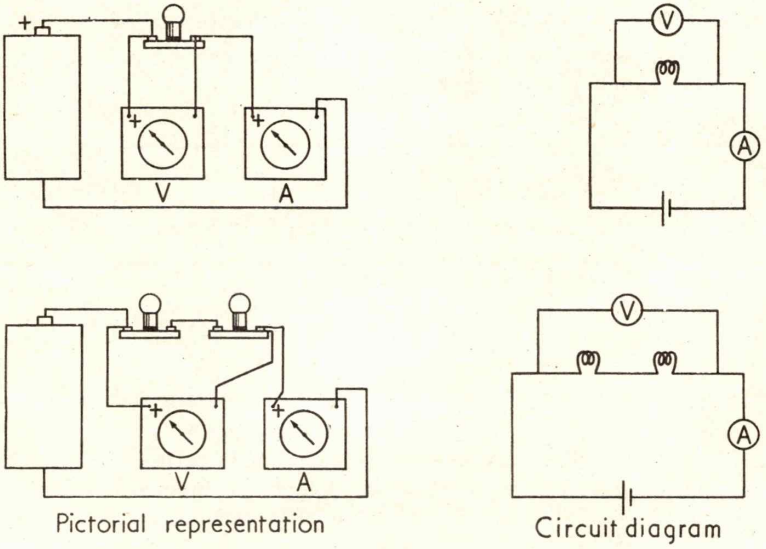


FIG. 85. Method of connecting meters: One cell and one lamp connected in series (*upper diagrams*); One cell and two lamps connected in series (*lower diagrams*).

PRECAUTIONS IN USING METERS

Meters are delicate instruments and are costly to replace. You will find fuller information on them on pp. 234-238. Before using them, however, note the following points.

1. An ammeter is used for measuring current flow. *Never connect an ammeter directly to a battery:* this short-circuits the battery, and also ruins the meter. Make sure the current has to flow through a resistance before flowing through the ammeter.
2. A voltmeter is used for measuring potential difference.
3. Both meters have one terminal marked +. Make sure that the wire beginning at the positive side of the battery is connected to this + terminal.
4. All meters must be handled with care—never bumped or dropped.

Tabulate your results as follows:

1.

Cells	*Voltage across lamp*	*Current*
1		
2 in series		

2.

Cells	*Lamps*	*Voltage across lamps*	*Current*
1	1		
1	2 in series		

The experiments you have just done demonstrate that when the voltage is doubled, the current is doubled; when the resistance is doubled, the current is halved. This is the simplest way of stating a law of fundamental importance in electricity—*Ohm's Law.*

Ohm's Law

We have seen that there is a definite relationship between the current flowing in a conductor, the potential difference, and the resistance of the conductor. This relationship is summed up in Ohm's Law, which may be stated mathematically as follows:

$$I = \frac{E}{R}$$

where I represents current in amps*

E is for the E.M.F. in volts

R is the resistance in ohms

*'C' cannot be used for current, as it is the symbol for capacitance. 'I' was adopted as it did not happen to be used for anything else.

Knowing any two of these quantities we can easily find the third by substituting the known values in the formula and solving the resulting simple equation. It is a simple matter to change the subject of the formula to obtain

$$E = IR$$

$$\text{and } R = \frac{E}{I}$$

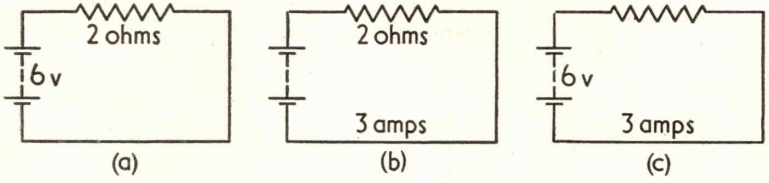


FIG. 86. Ohm's Law calculations.

The simple way in which we may calculate current, resistance, or voltage by Ohm's Law is illustrated by the simple circuits of *Fig. 86.*

(a) Required: current in amps $I = \frac{E}{R}$

$$= \frac{6}{2} = 3 \text{ amps}$$

(b) Required: p.d. in volts $E = IR$

$$= 3 \times 2 = 6 \text{ volts}$$

(c) Required: resistance in ohms $R = \frac{E}{I} = \frac{6}{3} = 2 \text{ ohms}$

EXAMPLES

1. An electric radiator takes 5 amperes of current when a pressure of 230 volts is applied to it. What is its resistance?

$$R = \frac{E}{I}$$

$$= \frac{230}{5}$$

$$= 46 \text{ ohms}$$

2. If the traffic indicator on a motor car is found to have a resistance of 6 ohms, and to require a current of 2 amperes to work properly, what pressure is necessary?

$$E = IR$$
$$= 2 \times 6$$
$$= 12 \text{ volts}$$

3. An electric lamp connected to a 200 volt supply has a resistance of 100 ohms. What current flows through it?

$$I = \frac{E}{R}$$
$$= \frac{200}{100}$$
$$= 2 \text{ amperes}$$

Always be careful to use the electrical units of measurement correctly. To talk of a current of 10 volts makes as much sense as saying you weigh 10 feet!

EXPERIMENT *To determine the value of a resistance by Ohm's Law.*

Connect a battery, a torch bulb, and an ammeter in series. Connect a voltmeter to the lamp terminals. Calculate the resistance of the lamp by dividing the pressure by the current.

$$R = \frac{E}{I}$$

SERIES AND PARALLEL CONNECTIONS

EXPERIMENT *Series and parallel connections.*

1. Join two torch bulbs in series ('one after the other'), and then connect to a 3-volt or 4½-volt battery with an ammeter in series. (See circuit diagram, *Fig. 87.*)
2. Note the reading of the ammeter.

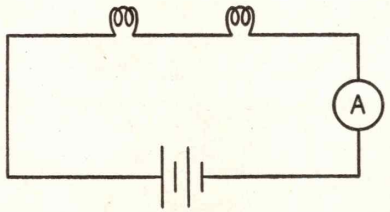


FIG. 87. Torch bulbs joined in series.

3. What happens when you screw out one of the torch bulbs?

4. Now join the two bulbs in parallel ('side by side'), and then connect to the battery in series with an ammeter. See Fig. 88.

5. Note the reading of the ammeter.

6. Screw out one of the bulbs; again read the ammeter.

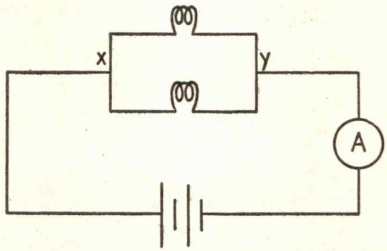


FIG. 88. Torch bulbs joined in parallel. The current divides at X and the two streams reunite at Y.

In the first case the circuit is broken by the removal of one of the lamps, and thus the ammeter shows no current flowing. When one of the lamps is removed from the parallel arrangement, however, current still flows, but the lower reading of the ammeter shows that the resistance of the circuit has been increased. Also, since the reading now obtained is still higher than that with two lamps in series it appears that, by arranging resistances

(i) in series—we increase the resistance;

(ii) in parallel—we decrease the resistance.

One advantage of series connection of lamps is the saving in wiring. But it would not do in our houses; for if one lamp went out the whole house would be in darkness. Each lamp must be connected in parallel so that it can be switched on or off independently of the others.

EXPERIMENT *Effective resistance of lamps in (a) series; (b) parallel.*

Use a voltmeter to read the potential difference across each of the torch lamps in the last experiment, then across (a) the series, (b) the parallel bracket. In each case, determine the resistance $\left(R = \frac{E}{I}\right)$

What is the resistance of each individual lamp? Of the two lamps in series? Of the two lamps in parallel?

Resistances in Series

In a series circuit the current is the same through all parts of the circuit. When resistances are connected in series the total resistance is equal to the sum of the individual resistances. Study the circuit shown in *Fig. 89.*

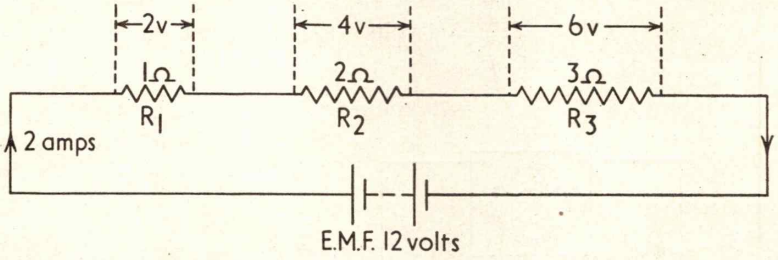


FIG. 89. Resistance in series.

This diagram shows three resistances connected in a series with a 12-volt battery. (R_1 means 'first resistance', and so on; the Greek letter omega (Ω) stands for ohms.)

$$R_1 = 1 \text{ ohm}; \; R_2 = 2 \text{ ohms}; \; R_3 = 3 \text{ ohms}.$$

Then the total resistance is found by adding them together:

$$\begin{aligned} R &= R_1 + R_2 + R_3 \ldots \\ &= 1 + 2 + 3 \\ &= 6 \textit{ ohms} \end{aligned}$$

The current flowing can be found by Ohm's Law:

$$\begin{aligned} I &= \frac{E}{R} \\ &= \frac{12}{6} \\ &= 2 \textit{ amperes} \end{aligned}$$

The current flowing through each of these resistances then, is 2 amps.

We can now calculate the 'voltage drop' across each resistance, i.e. the potential difference between the ends of each.

By Ohm's Law, $E = IR$

$R_1 = 1$ $E = 2 \times 1$

$= 2$ volts

$R_2 = 2$ $E = 2 \times 2$

$= 4$ volts

$R_3 = 3$ $E = 2 \times 3$

$= 6$ volts

The sum of these is 12 volts — the total E.M.F. of the battery.

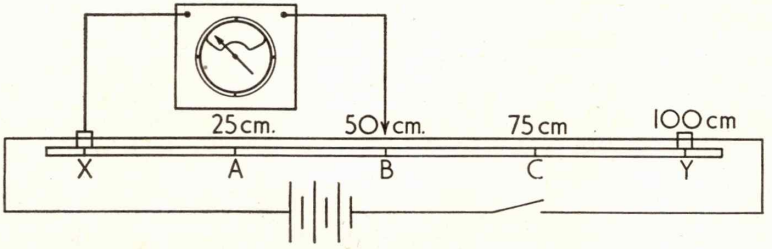


FIG. 90. Pressure drop. The arrow indicates a sliding contact.

EXPERIMENT *To investigate the pressure drop in an electric circuit.*

Fasten 100 cm of resistance wire* to a base-board, by means of screw terminals. Screw a metre rule to the board. Connect the terminals to a 6-volt accumulator.

Connect the + terminal of a voltmeter to terminal *X*, and a spring clip or test prod to the other terminal of the voltmeter.

Take voltmeter readings at points *X*, *A*, *B*, *C*, *Y* at the distances shown. Tabulate your work thus:

	Length of resistance wire	*Voltmeter readings*
XY	100 cm	6·0 volts
XC	75 cm	4·5 volts
XB	50 cm	3·0 volts
XA	25 cm	1·5 volts
X	0 cm	0·0 volts

As a current flows through a circuit there is a drop of pressure as each separate resistance takes so much pressure to drive the current through it.

*30 gauge Bright Ray resistance wire is suitable.

Remember: the current is the same through each resistance in a series circuit.

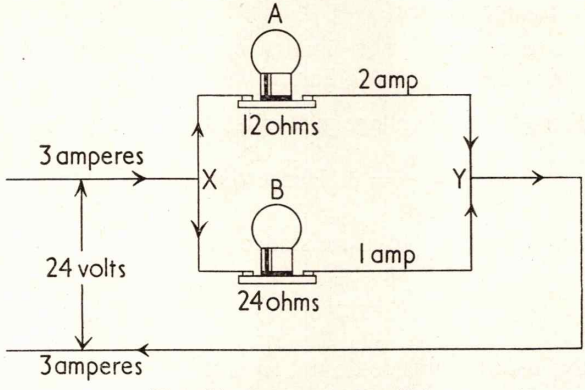


FIG. 91. Lamps in parallel.

RESISTANCES IN PARALLEL

In *Fig. 91* the current divides at X and the two streams unite again at Y. The current flowing through any part of a parallel circuit can be determined simply by Ohm's Law. In each of the above cases, for example, we divide the applied voltage by the resistance $I = \frac{E}{R}$. Of the total current of 3 amperes, 2 amperes flow through lamp A, and 1 ampere through lamp B.

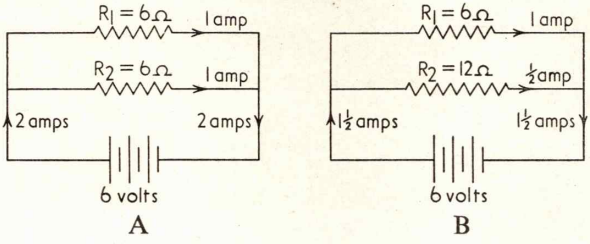


FIG. 92. Resistances in parallel.

Look at *Fig. 92* A. Two 6-ohm resistances are connected in parallel. By Ohm's Law, 1 ampere flows through each, so that the total current taken from the battery is 2 amperes. In circuit B, the current flowing through R_1 is 1 amp $\left(I = \frac{E}{R} = \frac{6}{6} = 1 \right)$; that through R_2 is ½ amp ($\frac{6}{12}$). The total current in this case is therefore 1½ amperes.

You should remember these facts:

1. When resistances are connected in parallel the total resistance is less than any one of them.

2. When two resistances of equal value are connected in parallel, the total resistance is equal to half of one of them.

For, in *Fig. 92* A, the voltage is 6 volts, the total current 2 amperes.

$R = \frac{E}{I} = \frac{6}{2} = 3$. Hence the *total* resistance is 3 ohms.

And, in *Fig. 92* B, the total resistance is 4 ohms.

$$\left(\quad R = \frac{E}{I} = \frac{6}{1\frac{1}{2}} = 4 \quad \right)$$

We always use the 'upside-down' formula for calculating the total resistance of resistances in parallel:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}, \text{ etc.}$$

EXAMPLE *Fig. 92* B.

$$\frac{1}{R} = \frac{1}{6} + \frac{1}{12}$$

$$= \frac{3}{12}$$

$$= \frac{1}{4}$$

R = 4 ohms. (Do not forget to invert ¼)

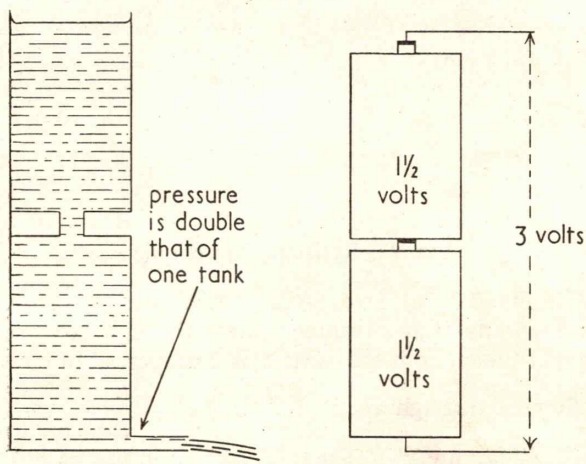


FIG. 93. Cells in series.

Cells in Series

You add the voltages of *cells* in series to find the total voltage of the battery. Thirty 1½-volt cells in series give a total voltage of 45 volts. (See *Fig. 93*)

Cells in Parallel

The voltage of cells in parallel is equal to the voltage of one cell. The total current is the sum of the currents through each cell.

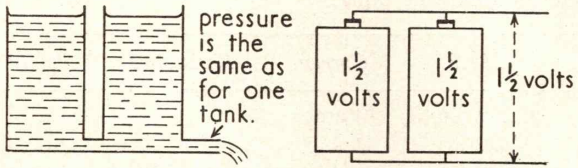


Fig. 94. Cells in parallel.

SUMMARY

1. Current flowing through a conductor is measured in amperes; the potential difference which produces the current flow is measured in volts; resistance, in ohms.
   A potential difference of 1 volt will drive a current of 1 ampere through a resistance of 1 ohm.

2. The relation between these units may be expressed simply as follows:
   In any electrical circuit, if the voltage is doubled the current is doubled; if the resistance is doubled, the current is halved.
   Ohm's Law states that 'the current through a given conductor is proportional to the potential difference between its ends provided the temperature remains constant'.

$$I = \frac{E}{R}; \qquad E = IR; \qquad R = \frac{E}{I}.$$

3. Resistances in series increase the total resistance, which is, in fact, equal to the sum of the individual resistances.

$$R = R_1 + R_2, \text{ etc.}$$

   The current through a series connection is the same for all parts of the circuit.

4. Resistances in parallel decrease the total resistance, which is, in fact, less than any one of the individual resistances. Total resistance may be calculated from the formula:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}, \text{ etc.}$$

5. The current in parallel arrangements is divided, the largest amount of current going through the smallest resistance. Current through each resistance may be determined by Ohm's Law.

6. The voltage obtained by connecting cells in series is equal to the sum of their voltages. The voltage of cells connected in parallel is the same as that of a single cell.

EXERCISE

1. Complete the following table:

No.	*E.M.F.*	*Current*	*Resistance*	*Power**
1	24 volts	4 amps		
2	220 ,,	5 ,,		
3	30 ,,		6 ohms	
4	110 ,,		22 ,,	
5		8 ,,	15 ,,	
6		1·5 ,,	4 ,,	
7	12 ,,			36 watts
8	230 ,,			460 ,,

2. Calculate the potential difference across a resistance of 12 ohms carrying a current of 3 amps.

3. An electric immersion heater which has a resistance of 57·5 ohms is connected to a 230-volt supply. Calculate the current.

4. What is the resistance of an electric iron if a current of 3 amps is used when it is connected to a 230-volt circuit?

5. What is the reading of a voltmeter connected across the terminals of a lamp which has a resistance of 230 ohms and takes a current of 0·5 amps?

6. Complete the following table:

No.	R_1	R_2	TOTAL RESISTANCE	
			In series	*In parallel*
1	4 ohms	12 ohms		
2	6 ,,	30 ,,		
3	12 ,,	36 ,,		
4	6 ,,	9 ,,		

*See *General Science*, page 397-8.

7. If the above resistances were connected to a 12 volt accumulator, what current would flow in each resistance?

8. A 2 Kw radiator has two bars connected in parallel. How much current would it use when it is connected to a 230 volt supply? What is the resistance of each bar?

9. An electric oven has two 1000 watt elements. Calculate the current that will flow when they are connected to a 230 volt supply and the switch is set to (*a*) low, (*b*) medium, and (*c*) high. (See page 206).

10. A circuit consists of a 6 ohm resistance in series with a parallel combination of 5 and 20 ohm resistances. Calculate the currents flowing in each of the three resistances when there is a p.d. of 20 volts across the whole circuit.

17

Heating and Chemical Effects of a Current

ELECTRIC HEATING

THE ELECTRICAL ENERGY used in overcoming the resistance of the conductor through which electricity is flowing is not lost, but is changed into another form of energy—heat. If the conductor offers a high resistance the heat generated by the flow of current may be so great as to make it red hot or even melt. Heat is produced even in a good conductor such as copper, but the amount is usually too small to notice.

EXPERIMENT *The heating effect of an electric current.*

1. Connect in series: a 6 volt accumulator, switch, 0-5 amp ammeter, 2-3 inches of resistance wire, 5 amp rheostat. Make the connections with fairly heavy copper wire. When using accumulators it is always a good precaution to use a piece of 5 amp fuse wire to connect with one terminal.

2. Slowly increase the current by means of the sliding contact on the rheostat, keeping a constant eye on the ammeter.

As the current increases, the resistance wire becomes hot and may eventually burn right through. Does the thick copper connecting wire heat up?

We deduce from this experiment that the heating effect of an electric current depends on . . .

(i) current (ii) resistance

Actually, the heat generated in a wire is proportional to ( ) the resistance of the wire, (ii) the square of the current, (iii) the time for which the current passes. In electric radiators, irons, blankets, and so on, we make use of this heating effect. The elements are made of high-resistance wire, usually an alloy such as nichrome, which does not oxidize readily when heated.

The Tungsten Lamp

You have seen that if a wire has a high resistance it quickly becomes red-hot when sufficient electric current is passed through it. The ordinary electric lamp contains a tungsten filament—a very thin wire of high resistance. When current at the correct voltage passes through it, it becomes white-hot and so emits light. Only about ten per cent of the electrical energy is converted into light, the rest being wasted as heat.

The earliest successful electric lamps were produced by Edison in America and Swan in England, about 1880. Both used in their lamps a fine thread of carbon, as there was no metal known that would not melt with the great heat. The air was pumped out of the bulb so that the carbon would not burn. However, the lamp was a poor one compared with the lamp of today. The filament in a carbon lamp could not be made hot enough to give a good light. It ran at a temperature of about 1600°C; the gas-filled tungsten lamp runs at a temperature of about 2700°C. Moreover, the carbon lamp did not last long on account of the slow evaporation of the carbon, which blackened the lamp.

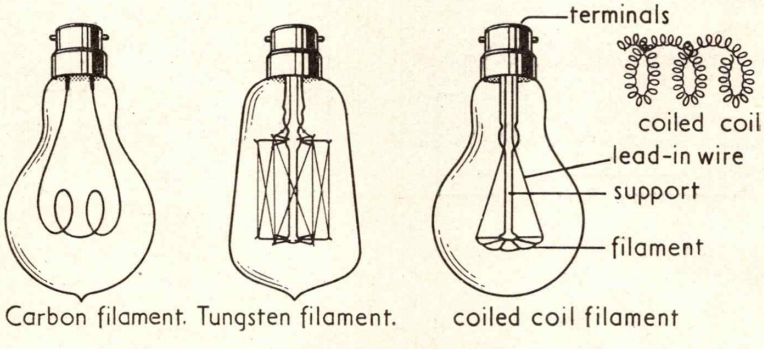


FIG. 95. Filament lamps.

The fine tungsten filament of the modern lamp has the advantages of strength combined with ability to withstand great heat without melting. Air is removed from the bulb and replaced by an inert gas, argon, or argon and nitrogen, in which the filament will not oxidize. The tungsten wire is close-coiled, the turns being very close together and thus helping to keep each other hot.

The efficiency of the gas-filled tungsten lamp is usually about one watt per candle-power.

If you examine an electric lamp you will see its voltage and power rating stamped on it. A lamp must not be used on any voltage other than that for which it was designed. If a higher voltage is used, the filament will soon melt; with a lower voltage the lamp will not light up properly. The lamp in your room may be marked '230 v. 100 w.'. This means that it is the correct lamp to use with our power supply (230 v) and that it uses 100 watts. It will consume one unit of electrical energy in 10 hours' running (see *General Science*, page 399).

Three-heat Switches

Electric ovens and water urns usually have a useful switching device providing a range of three heats—high, medium, or low. The heating elements are made in two separate coils, and the three stages of heat output are obtained simply by using the two coils in series (low), one coil only (medium), and two coils in parallel (high).

Some heating devices are provided with a *thermostat* for keeping the temperature steady. When the temperature reaches a predetermined maximum a metal strip bends sufficiently to break the circuit.

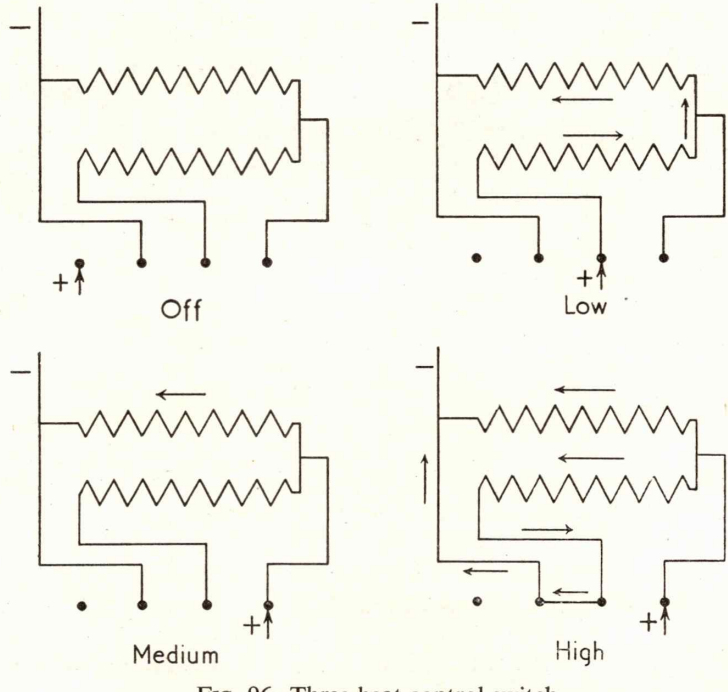


Fig. 96. Three-heat control switch.

Great care is taken to avoid as far as possible electric heating where it is not wanted. All the wiring in your house is of such a thickness that it will carry the maximum current required of it without heating unduly. Where heating appliances requiring a heavy current are used, specially heavy wires are provided and connected to three-pin power plugs. You can see why it is foolish to work heating appliances from lamp sockets. When the metal contacts in electrical connections become dirty or corroded, their increased resistance causes them to overheat. Three-pin plugs frequently get hot for this reason.

THE CHEMICAL EFFECT OF A CURRENT

In the experiment on page 79 it was found that water was split up into hydrogen and oxygen by the action of an electric current. Now it is necessary to learn something more about the process of electrolysis.

EXPERIMENT *To study the effect of an electric current on water.*

Repeat the experiment described on page 79, but this time fill the voltameter with a dilute solution of sodium sulphate to which some litmus has been added. After a few minutes you will notice that the litmus in the anode arm will turn red while that in the cathode will be blue.

In your earlier work you learned that there are three types of liquid:

1. Those which conduct an electric current and do not suffer any change, e.g. mercury.
2. Compounds which conduct electricity but which suffer a chemical change in the process. These are called electrolytes and the decomposition that takes place is known as electrolysis, e.g. molten salts and solutions of acids, bases, and salts.
3. Non-electrolytes, which do not conduct an electric current, e.g. petrol.

In this section, we are concerned only with the second type, and the following is a simplified explanation of the changes that take place.

When acids, bases, and salts are dissolved in water, they split up into particles called 'ions'. The metal of a salt or alkali, and the hydrogen of an acid, are positively charged, whereas the hydroxyl group of an alkali and the acid radical of an acid or salt are negatively charged.

$$HCl \rightarrow H^+ + Cl^-$$

$$NaNO_3 \rightarrow Na^+ + NO_3^-$$

$$KOH \rightarrow K^+ + OH^-$$

These ions must not be confused with atoms: their properties are quite different. Common salt, for example, yields sodium ions which do not react with water as metallic sodium would; and chloride ions which are not poisonous like the gas.

In a similar manner, some of the water molecules split up into hydrogen and hydroxyl ions, but as there are comparatively few of these under normal conditions, pure water is a poor conductor. However, its conductivity can be increased considerably by dissolving a small quantity of an acid, alkali, or salt which splits up almost completely and yields large numbers of ions.

In your experiment, the sodium sulphate split up into sodium ions and sulphate ions, and these enabled sufficient current to flow to electrolyze the water.

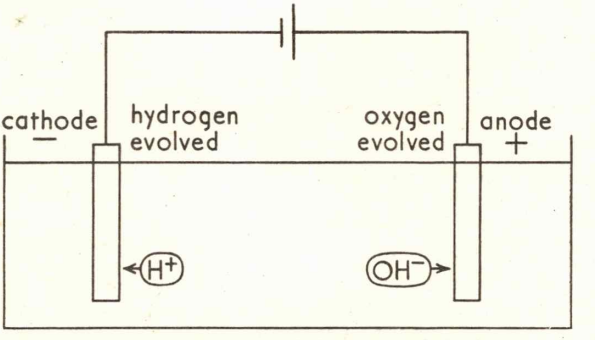


FIG. 97. Chemical effect of a current: electrolysis of water.

At the cathode, the hydrogen ions lose their charge and become normal hydrogen which is liberated. This leaves surplus hydroxyl ions and this fact accounts for the presence of sodium hydroxide (litmus turns blue).

Similarly, the hydroxyl ions, being negatively charged, are attracted to the positively charged anode, where they give up their charge.

$$4OH \rightarrow 2H_2O + O_2$$

As they are removed there will be surplus hydrogen ions, and this explains the presence of sulphuric acid (hydrogen and sulphate ions), turning the litmus red. As the gases are discharged, more of the water splits up into hydrogen and hydroxyl ions.

Electrolysis is widely used commercially for the electroplating of metals. When you have carried out the following experiment you will understand how this is done.

EXPERIMENT *To copper-plate a metal object.*

In a solution of copper sulphate place a strip of copper connected to the positive terminal of the battery, and a piece of platinum wire which is connected to the negative terminal of the battery.

Switch on the current. After a while you will notice the wire changing colour: it is getting coated with copper. What is happening to the copper anode (i.e. the copper strip connected to the positive battery terminal)?

In solution, the copper sulphate is completely ionised into copper ions and sulphate ions. As the copper ions are more easily discharged than the hydrogen ions (from the water), they lose their charge first and are deposited on the cathode as metallic copper.

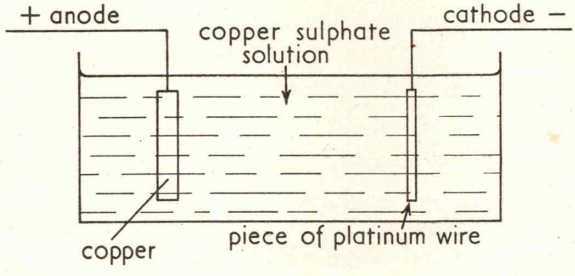


FIG. 98. Copper plating.

At the anode, neither the sulphate nor the hydroxyl ions are discharged, as it is easier for the metallic copper to be converted into copper ions. Thus the copper anode will appear to dissolve. As there will be as many copper ions formed at the anode as are discharged at the cathode, the solution will not change in strength. In effect, the process transfers copper from the anode to the cathode.

ELECTROPLATING

The method used in the last experiment is similar to that used for commercial electroplating. Cheap metals can be covered with silver or gold, a salt of the metal required being used as the electrolyte. Metals such as iron are coated with a durable non-rusting metal such as chromium. The metal to be coated must first be made perfectly clean, and free from all grease and rust. It is scrubbed with wire brushes or sand-blasted, and then treated in a solution such as warm sulphuric acid.

SECONDARY BATTERIES

The secondary cell or lead accumulator is made by the electrolysis of sulphuric acid solution, using lead electrodes. This is one of the most important applications of electrolysis.

ELECTROTYPING

Type-settings of the pages of a book are often copied by electrolysis. The original block of type is pressed on a sheet of wax, which is then given a coating of graphite. The sheet of wax is then made the cathode in a copper sulphate solution and receives a coating of

copper. The wax is removed and the copper is strengthened by a backing of molten metal. The copy thus made is used to save wear on the original.

Purification of Copper

Impurities in copper are removed by using plates of the impure metal as anodes, and sheets of pure copper as cathodes, in electrolytic cells containing copper sulphate. Pure copper is deposited on the cathodes.

Manufacture of Chemicals

Sodium hydroxide is manufactured by the electrolysis of common salt. Hydrogen and oxygen are in some instances obtained by the electrolysis of a solution of sodium hydroxide.

Production of Metals

The source of aluminium is a mineral called bauxite, a hydrated oxide of the metal. After purification, the oxide (Al_2O_3) is dissolved in another mineral, cryolite, and electrolysed. Aluminium is liberated at the cathode. All the metals above aluminium in the 'Replacement Series' (pp. 94-7) are obtained by some electrolytic process.

SUMMARY

1. Solutions of acids, bases, and salts which conduct electricity and are decomposed by it are called *electrolytes*.
2. The plates dipping into the electrolyte and connected to the direct current supply are called the *electrodes*. The positive electrode is known as the *anode;* the negative, the *cathode*.
3. *Electrolysis* takes place when an electric current is passed through an electrolyte. Hydrogen in acids, and the metals in salts and alkalis, are liberated at the cathode; oxygen and the non-metals at the anode.
4. Electrolysis is of great commercial importance. It is used in the manufacture of secondary batteries, and in the electrical deposition of metals, in electrotyping, in the purification of copper, in the production of metals, and in electroplating. It is also used in the manufacture of chemicals.

18

Magnetism

MAGNETS

THOUSANDS OF YEARS AGO the ancients knew that a certain stone possessed the property of attracting some metals. Also, it always pointed in one direction when it was suspended by a fine thread, and so was called 'lodestone', which means 'leading stone'. These natural magnets we know to be a magnetic oxide of iron (Fe_3O_4), often called 'magnetite', since it was first recorded as being found in Magnesia in Asia Minor.

EXPERIMENT *To study the properties of a magnet.*

1. Hold one end of a bar magnet near small pieces of copper, brass, aluminium, wood, glass, tin, iron, nickel, and as many other substances as you can, and note which of them is attracted.

You will notice that iron and steel are the only common substances* the magnet will attract. All other substances are termed 'non-magnetic'.

2. Dip a bar magnet into iron filings, and shake it gently. Notice that large clusters of filings remain about the ends of the magnet—none at all at the middle.

A magnet is weakest at its centre. The ends where the magnetic property is strongest are called the poles.

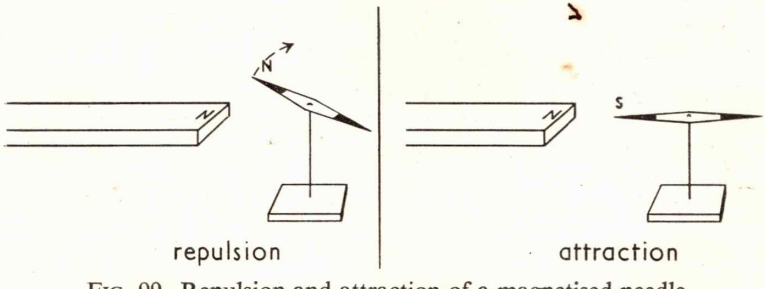


FIG. 99. Repulsion and attraction of a magnetised needle.

*Other magnetic substances are nickel, cobalt and some of their alloys containing aluminium, copper or manganese, e.g. alnico.

3. Suspend a bar magnet horizontally by means of a paper stirrup, and a thread of silk or nylon. The magnet comes to rest with its axis pointing approximately in a north-and-south direction.

Every magnet has a north-seeking pole, and a south-seeking pole, called the N pole and the S pole respectively.

4. Bring the N pole of another magnet near the N pole of the suspended magnet and observe the repulsion. Now bring the S pole to the N pole of the suspended magnet: note the attraction.

Unlike poles attract each other
Like poles repel each other

Induced Magnetism

EXPERIMENT Hold a piece of soft iron near some iron filings: nothing happens. Now hold an alnico magnet near the end of the soft iron farthest from the filings. Observe that filings are now attracted; but they drop off when the alnico magnet is removed.

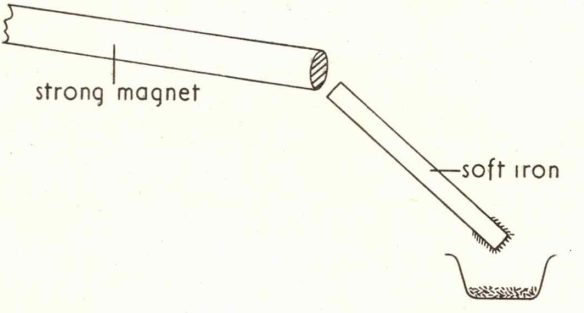


FIG. 100. Magnetism induced in soft iron rod.

The soft iron becomes an *induced magnet* when a permanent magnet is held near it or in contact with it.

EXPERIMENT Using a permanent magnet, make a chain of steel pins as shown in Figure 101. This is another demonstration of induced magnetism.

When the magnet is brought near a steel pin, the pin becomes magnetized by induction, and the induced pole nearest to the magnet is of opposite polarity to the nearest pole of the magnet. Unlike poles attract each other: the pin is thus attracted to the magnet. Magnetic induction always precedes magnetic attraction.

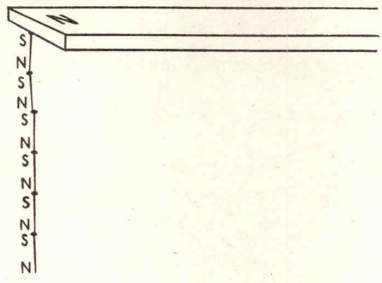


FIG. 101. Magnetism induced in steel pins.

TEST FOR A MAGNET

Bring one end of a piece of soft iron up to the N pole of a compass needle, which, of course, is a small permanent magnet pivoted at its point of balance. Now try the same end of the soft iron at the S pole. Repeat the experiment using a magnetized knitting needle. Note that one end of the magnetized needle *repels* one pole of the compass needle, whereas there is mutual attraction between both ends of the soft iron rod and any pole of the compass needle.

Thus a compass needle may be used to find which is the N and which is the S pole of a magnet, or to discover whether a piece of iron is a magnet at all. The only real test for magnetism is the *repulsion* of one pole of a magnet by one end of the supposed magnet.

MAGNETIC FIELDS

The space surrounding a magnet—the region where its force acts, is called a *magnetic field.*

EXPERIMENT *To study the magnetic fields around bar magnets.*

1. Place a bar magnet on a bench, and on top of it lay a sheet of stiff paper or cardboard. Sprinkle over the paper some iron filings, and tap the paper gently. Note the pattern in which the iron filings set themselves, and make a drawing of it.

2. Repeat the above procedure, this time having two magnets in line with
   a. the N pole of one bar magnet about one inch away from the S pole of the other;
   b. the N poles of both magnets near each other.

Draw the resulting patterns.

3. Finally, place two bar magnets parallel with each other and about two inches apart with a. unlike poles opposite each other,

b. like poles opposite each other.

Again draw the fields.

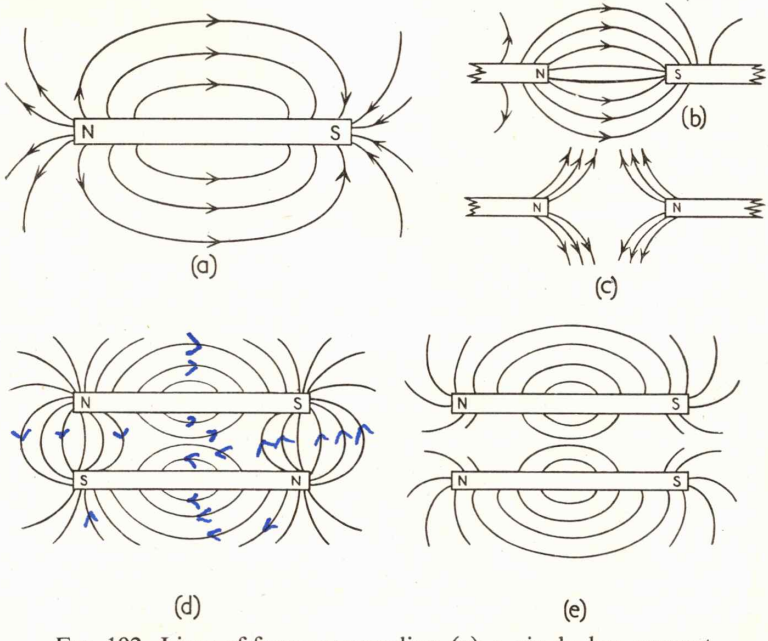


FIG. 102. Lines of force surrounding (a) a single bar magnet, (b) unlike poles, (c) like poles, (d) and (e) pairs of bar magnets.

The lines along which the iron filings set themselves are called 'lines of force'. These lines of force show the direction in which the magnetic force is exerted. Following the suggestion of Faraday, we use arrowheads on lines of force indicating the direction in which a N pole would move if it were free to do so. If we place a small compass in a magnetic field, its N pole indicates the direction of the field. One method of drawing a magnetic field is to use a small 'charm compass', making dots to represent the direction of the compass needle as it is moved about the magnet.

When you have finished your diagram of magnetic fields, notice particularly these facts:

1. Lines of force join unlike poles, but never join like poles.
2. Lines of force do not cross one another, but tend to diverge as widely as possible.

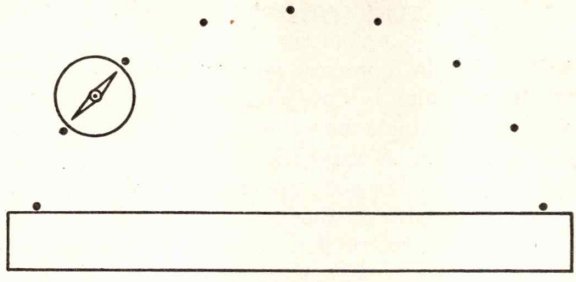


FIG. 103. Plotting a magnetic field.

THE EARTH IS A MAGNET

Why is it that if a magnet is freely suspended it sets in a N-S direction? Gilbert was the first to give the answer: the earth itself is a magnet with a pole of S-seeking polarity near the geographic North Pole and one of N-seeking polarity near the geographic South Pole. The former is called the N magnetic pole, the latter the S magnetic pole. Surrounding the earth is its magnetic field, and the direction in which a magnet sets itself in this field is called the *magnetic meridian.*

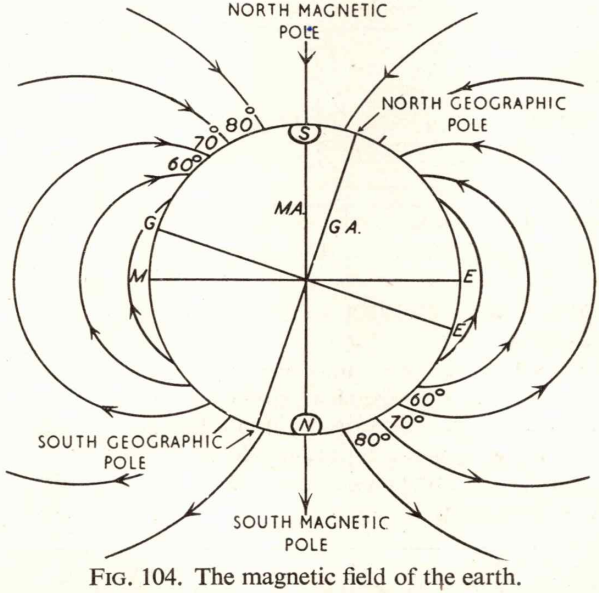


FIG. 104. The magnetic field of the earth.

MA Magnetic axis
GA Geographical axis
ME Magnetic equator
GE Geographical equator

Since the magnetic poles and geographic poles do not coincide, the direction in which a compass sets itself is not strictly N-S.

In New Zealand the compass points about 20 degrees east of north. This angle, which is slowly changing, is called the *magnetic declination*. It is the angle between the magnetic and geographic meridians. Actually the N magnetic pole is situated approximately 20 degrees south of the N geographic pole, and moves completely round the pole, east to west, once in approximately 960 years. The reason for this movement of the magnetic pole is not yet known.

The Dip Needle

A 'dip needle' is a magnetic needle pivoted to enable it to rotate in a vertical plane. It is turned until it is in line with the magnetic meridian, when it will arrange itself parallel with the earth's magnetic lines of force. The angle of dip will vary from 0° at the magnetic equator to 90° at the magnetic poles. In Wellington the angle of dip is about 66°. This is the angle the dipping needle makes with the horizontal and is called the *inclination* of the locality.

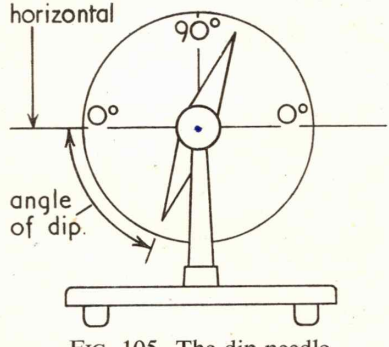


Fig. 105. The dip needle.

The Molecular Theory of Magnetism

EXPERIMENT Magnetize a steel knitting needle or a piece of clockspring by stroking it with a bar magnet. Break it in half or cut it with a pair of pliers. Test the pieces so obtained with a compass needle. Now break each of the two pieces again into halves, and test each piece.

It will be found that each time the magnetized needle is divided into two parts, two new poles appear. Each piece has a N pole and a S pole.

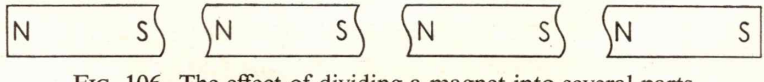


Fig. 106. The effect of dividing a magnet into several parts.

What would happen if we could go on breaking these magnets until the smallest particles of iron that can exist were obtained? The molecular theory of magnetism assumes that we would then have the smallest possible magnet, i.e. a magnetic molecule. In an unmagnetized rod of iron all these tiny magnets are pointing in various directions: in fact, arranged in closed chains, N poles attracting S poles. When the bar is stroked with a bar magnet all these tiny magnets are rearranged with the N poles all pointing in the same direction.

FIG. 107. Diagram illustrating the arrangement of molecular magnets before and after bar is magnetized.

EXPERIMENT Fill a small test-tube with iron filings and cork it firmly. Test it for magnetism, using the repulsion test at a compass needle. Now lay it on the bench and stroke it end to end in the same direction with one pole of a bar magnet. Again test for magnetism, taking care not to disturb the iron filings.

It will be found that the iron filings are not magnetized in the first place; but, after the tube is stroked with the magnet, it gives the repulsion test of a magnet, i.e. it repels one pole of the compass needle.

Now shake up the test-tube and test again for magnetism. It will be found that no magnetic properties are now in evidence.

This theory explains why magnets are strongest at the poles. At the ends there are rows of un-neutralized poles which tend to spread apart because of mutual repulsion. In the middle of the chains N and S poles are adjacent and so neutralize each other's effects.

When a magnet is strongly heated or violently struck or dropped, these tiny magnets are bumped out of alignment and so the magnet loses its strength. When as many molecules as possible are aligned within a bar of iron it is as strong a magnet as it can possibly be. It is then said to have reached magnetic saturation. The magnet itself is not weakened when it is used to magnetize another bar.

It is much easier to magnetize soft iron than hard steel, but the soft iron loses its magnetism much more readily. This is because the attraction between the molecules in hard steel is much stronger than it is in soft iron. The magnetic properties of soft iron make it ideal for use in a type of magnet called an electro-magnet which we shall consider later on (pp. 227-8).

EXPERIMENT *Methods of making magnets.*

Some of the methods have already been mentioned, and we will now list them:

1. *By tapping.* Take a rod of iron, about 3 ft long, and test it to make sure it is not magnetized. Hold it in a N-S direction and pointing downwards towards the south, i.e. in the same direction as the earth's magnetic field. Tap it with a mallet. The tapping of the rod shakes the molecules into alignment, and of course can shake them out of alignment, too, if the rod is not parallel to the earth's magnetic field. Many steel buildings, poles, and ships are magnetized by constant vibration.

2. *By stroking.* One pole of a bar magnet may be used to stroke the bar of iron from end to end, or it may be stroked from its middle outwards by N and S poles (see *Fig. 108*). Lift the magnet well clear of the bar at the end of each stroke.

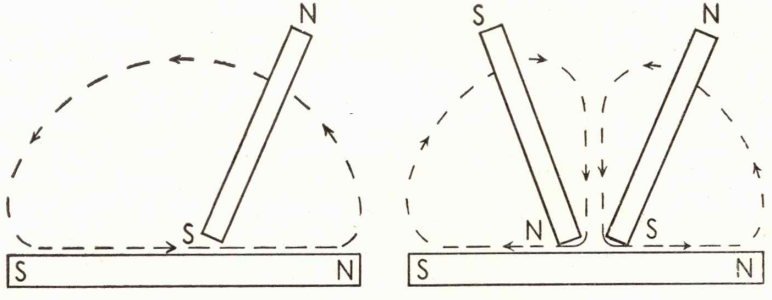


FIG. 108. Making magnets.

3. *By means of an electric current.* As we shall see later (see p. 228), a bar of iron may be magnetized by being placed in a solenoid through which an electric current is flowing. This is the most efficient way of magnetizing a magnetic substance.

MAGNETIC ALLOYS

As you have learned in another section (p. 92), alloys exhibit properties not possessed by their individual constituents. Thus one alloy containing manganese, aluminium, and copper is strongly magnetic, whereas none of the metals comprising it is magnetic by itself. Other alloys, more easily magnetized and demagnetized than soft iron, are used in electrical transformers. The alloy 'Alnico' so named because of the metals comprising it—aluminium, nickel, and cobalt—is used to make very strong permanent magnets, such as are required in the permanent magnet type of loudspeaker in radio sets.

Care of Magnets

You will now understand the reason why magnets should be handled with care, not dropped carelessly on the bench, or worse, on the floor. They must *never* be heated, since heating destroys magnetism. Bar magnets should always be stored in pairs, separated by a strip of wood, complete with soft-iron 'keepers' across their ends. Unlike poles are induced in the keepers and the effect is to keep the chains of molecules joined up in closed curves, thus reducing the tendency to get out of alignment.

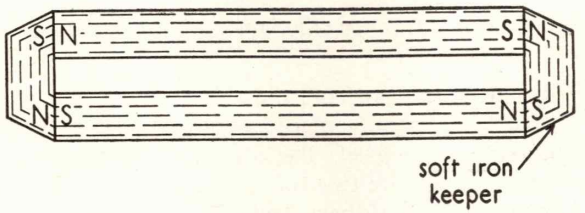


Fig. 109. How to store magnets.

The Mariner's Compass

A ship's compass must be quick in action, come to rest quickly, and be mounted so as to keep its horizontal position however the ship may roll. Moreover, it must be protected from the magnetic influence of the ship itself.

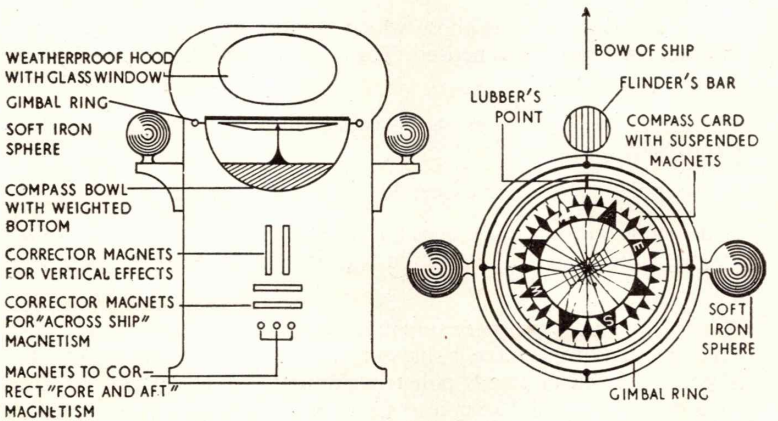


Fig. 110. The mariner's compass.

To satisfy these requirements, the mariner's compass is constructed in the following manner:

(1) The circular card, divided into the 32 points of the compass, has about eight magnetic needles, 2 to 3 inches long, tied beneath it by silk threads. It is pivoted on a hard steel point in an agate crown.

(2) The movement of the card is damped. It is enclosed in a copper bowl filled with a mixture of water and spirits which prevents excessive movement.

(3) The compass is mounted on a gimbal having two sets of axes perpendicular to one another, the outer set being attached to the binnacle (*Fig. 110*).

(4) To protect the compass from the ship's magnetism, permanent magnets in pairs are usually placed beneath it both parallel with and at right angles to the keel. The compass is housed in a binnacle on the outside of which are two soft iron spheres and a vertical bar of soft-iron called a Flinder's bar. These are to counteract the varying induced magnetism of the ship.

Whenever major repairs have been done on a ship the compass has to be corrected. This is because of the influence of the earth's field when the ship is subjected to hammering and rivetting. In the process of 'swinging the ship', the correcting magnets in the binnacle are altered while the ship cruises round in a circle keeping a bearing on a landmark.

SUMMARY

1. Magnetic substances are those which are attracted by a magnet, and are capable of being magnetized. They are iron and steel, nickel, cobalt, and certain alloys.

2. A magnet has two poles—a N-seeking and a S-seeking pole. It is strongest at the poles.

3. Unlike poles attract each other; like poles repel each other.

4. A magnetic substance becomes an *induced magnet* when a permanent magnet is held near it. Attraction between the unlike poles then takes place.

5. A *magnetic field* is the space surrounding a magnet where its force acts. The direction of this force is shown by *lines of force*, which indicate the direction in which a free N pole tends to move.
   Lines of force join unlike poles, but never join like poles.
   Lines of force do not cross one another, but tend to diverge as widely as possible.

6. The earth itself is a magnet, the magnetic poles being situated about 20° from the geographic poles. It is on account of the earth's magnetism that a freely-suspended magnet sets N. and S.

7. The molecular theory of magnetism assumes that iron is composed of groups of molecules which are magnets. When these molecules are aligned the iron shows magnetic properties.

8. Soft iron is more readily magnetized than steel, and loses its magnetism more readily.

9. Magnets should be handled gently, and stored complete with keepers.

19

Magnetic Effects of a Current

ELECTRO-MAGNETS

ONE OF THE MOST IMPORTANT and useful effects of an electric current is its magnetic effect. Electric bells, relays, motors, and other devices are applications of it. It was long believed that there was some connection between electricity and magnetism, but it was not until about 1820 that Hans Christian Oersted, of Copenhagen, became the first to demonstrate it. He noticed that when he switched on the current in a circuit, a compass needle placed near the wire turned at right angles to it. You should perform Oersted's experiment and observe the effect for yourself.

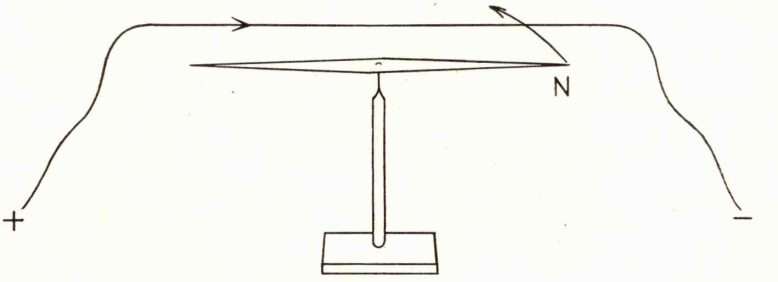


FIG. 111. Magnetic effect of electric current.

EXPERIMENT *To show the magnetic effect of an electric current.*

Connect a length of copper wire to a battery* and hold it parallel with a compass needle (a) above, (b) below the needle. Reverse the direction of the wire and repeat the experiment. Try again with the wire disconnected from the battery. Record your observations in four diagrams. You will obtain the results shown in *Fig. 112.*

*In order to avoid short-circuiting the battery you must have a resistance in series with your wire. This resistance could be a lamp, or just a length of resistance wire.

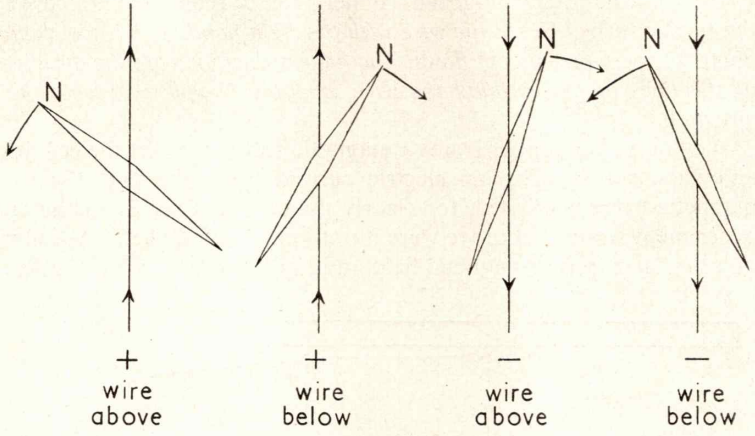


FIG. 112. The effect of a conductor carrying a current when held above and below a compass needle.

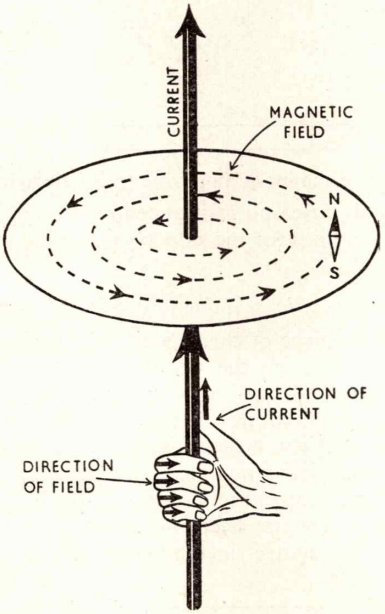


FIG. 113. The right-hand grasping rule.

The right-hand grasping rule will help you to remember which way the needle turns. *Grasp the wire with the right hand so that the thumb points the way the current flows. The fingers then indicate the direction of the lines of force round the wire, and the N pole moves in their direction.*

We know that copper is not a magnetic substance, yet the remarkable fact is that when an electric current flows through a wire a magnetic force is created, for clearly the compass needle in the last experiment would not move were it not in a magnetic field. We must now try to map this magnetic field and find in what direction it acts.

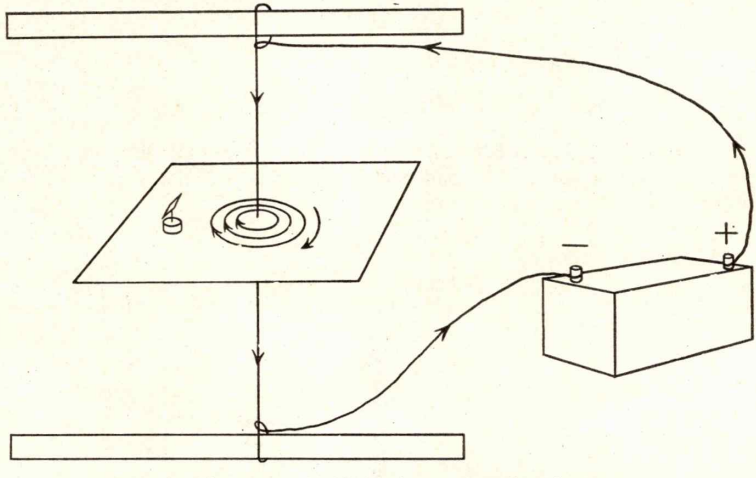


FIG. 114. The magnetic field due to an electric current.
Note: Switch, fuse and resistance are omitted from this diagram for the sake of simplicity.

EXPERIMENT *The magnetic field due to an electric current.*

Take a piece of card about 3 in. square and pass a piece of stout copper wire through the middle of it. You will need burette stands to hold the wire and card in the position shown in *Fig. 114.*

Connect the ends of the copper wire to a 6-volt accumulator in series with a switch.* Sprinkle iron filings evenly on the card, and later substitute four 'charm' compasses in a circle about the wire.

Close the switch for a moment or two only—to allow just sufficient time to give the card a tap. Do not keep the switch closed for long, for you have a circuit of low resistance since a heavy current is required for this experiment.

*In order to avoid short-circuiting the battery, it is advisable to have a resistance in series; to be on the safe side, connect a piece of 10 amp fuse wire in series with it.

Reverse the current and repeat the experiment.

The filings arrange themselves in concentric circles, and the way the small compasses set will show you the direction a free N pole would move if it were free to do so.

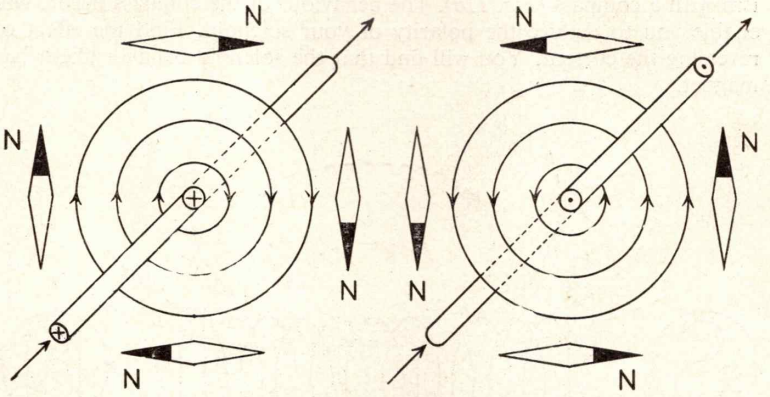


FIG. 115. A wire carrying a current, showing the direction of the magnetic field.

THE SOLENOID

The magnetic force produced about a long length of wire is very strong when concentrated into a smaller space by winding the wire into a coil. The wire must be insulated, of course, or the current would not flow around the turns. Wire used for this purpose is usually either enamelled or double-cotton covered. Such a coil of wire is called a *solenoid.*

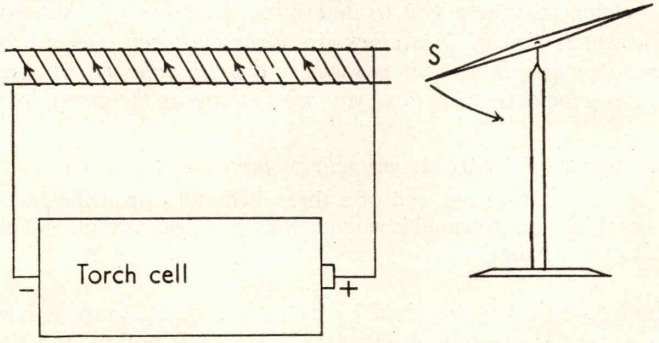


FIG. 116. A solenoid through which a current is flowing behaves like a magnet.

EXPERIMENT *To make a solenoid.*

Wind 2 or 3 yards of enamelled wire (24 or 26 gauge) neatly and closely on a piece of glass or cardboard tubing about 3 inches long and $\frac{1}{2}$ inch in diameter. Connect it to a torch cell and test for magnetism with a compass (*Fig. 116*). The behaviour of the compass needle will enable you to deduce the polarity of your solenoid. Find the effect of reversing the current. You will find that the solenoid behaves like a bar magnet.

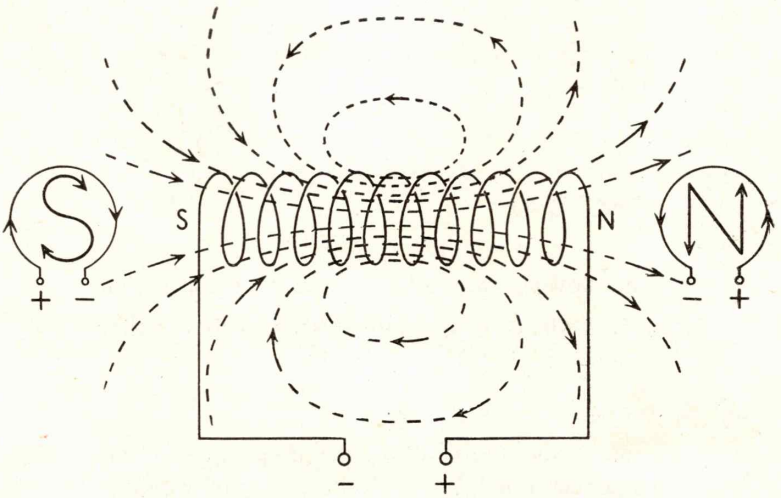


FIG. 117. The magnetic field around a solenoid.

In addition to the right-hand rule (p. 223), there is another simple guide which may help you to determine the poles of a solenoid. *If the current is flowing in a clockwise direction when you are looking at the solenoid end on, that end will be a south pole. If the current is in an anti-clockwise direction, you are looking at the north pole.*

EXPERIMENT *To study the magnetic properties of a solenoid.*

Place one end of a three-inch nail just in the end of the tube on which your solenoid is wound. Switch on the current, and observe what happens to the nail.

The iron nail is magnetized by induction (p. 212) just as it would be by a permanent magnet. But the solenoid is hollow and the nail goes right into it.

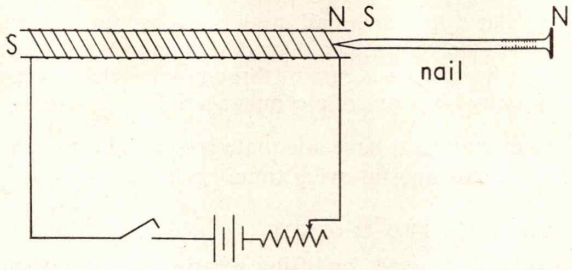


FIG. 118. When the switch is closed, the nail is attracted into the solenoid.

This property of the solenoid is used in motor car trafficators. When switched on, the current flows through a solenoid into which a soft iron bar is attracted. The indicator arm is pivoted to this soft iron bar.

THE ELECTRO-MAGNET

The magnetic force of a solenoid may be greatly increased by providing it with an *iron core*. The iron becomes magnetized and its magnetism is added to that of the solenoid. Such an arrangement is called an *electro-magnet*.

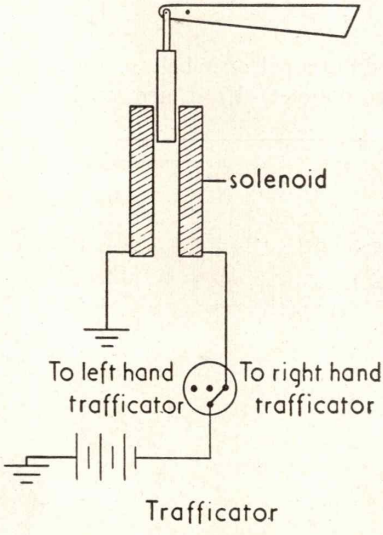


FIG. 119. A direction indicator used on motor cars.

EXPERIMENT Put a four-inch nail inside the glass tube on which you wound your solenoid, or rewind your 2 or 3 yards of wire on any nail you have. Pass a current through your electro-magnet and ascertain its polarity by means of a compass needle.

NOTE Every circuit must have adequate resistance. It is good practice to use a rheostat every time.

Uses of the Electro-magnet

Electro-magnets are used for lifting scrap iron, girders, nails and such like, and for separating iron from non-magnetic metals such as copper. They are also used for extracting iron or steel filings from the eye.

EXPERIMENT Place a rod of soft iron in a solenoid and connect the solenoid to a battery and switch. Hold one end of the soft iron rod near some iron filings. Switch the current on, and then off. Repeat, using a rod of steel in the solenoid.

You will observe that both attract a large cluster of iron filings when the current is switched on. When the current is switched off, the iron filings drop from the soft iron core, but not from the steel. Soft iron, as we have seen, is readily magnetized, and loses its magnetism readily, whereas steel, though more difficult to magnetize, retains its magnetism.

The Electric Bell

The construction of an electric bell is shown in *Fig. 120.* The parts are (A) an electro-magnet, (B) an armature, (C) a contact breaker.

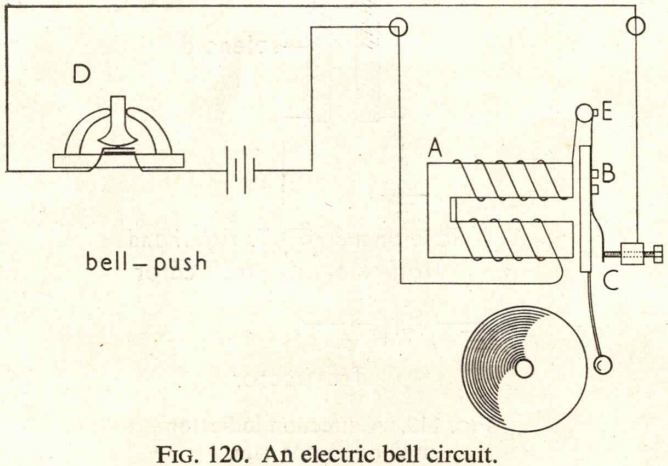


FIG. 120. An electric bell circuit.

When the bell-push (D) is pressed the circuit is completed, and electro-magnet (A) attracts armature (B) towards it. This makes the clapper strike the gong, and also makes a break in the circuit at (C). The current thus stops flowing, the electro-magnet loses its magnetism, and the armature is returned to its original position by the spring (E) to which it is attached. The cycle then is repeated rapidly.

THE RELAY

In the above bell circuit difficulty would be met if the switch had to be placed a considerable distance from the bell. Why? Remember that if you double the length of a wire you double its resistance. Double the resistance means half the current. If the connecting wires are too long, the resistance is so great that the battery cannot drive enough current to make the bell ring. This difficulty is overcome by means of the type of switch shown in *Fig. 121.* It is called a 'relay'.

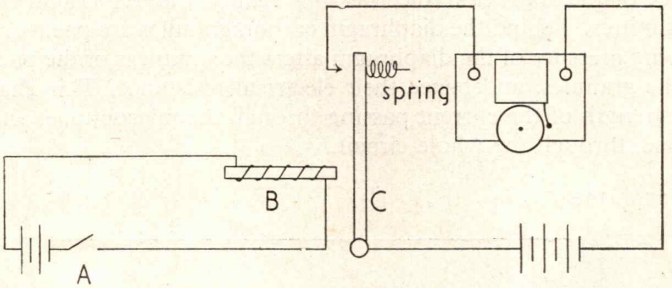


FIG. 121. A relay. (A) Switch of small current circuit; (B) Electro-magnet of relay; (C) Moving arm.

The feeble current through electro-magnet B is sufficient to make it attract the soft iron strip C, thus switching on the bell in a separate circuit.

Relays are widely used in motor cars for switching on the self-starter motor and headlamps. They are used in long-distance telegraphy; and in hydro-electric stations (large-current circuits can be controlled by switches in low-current circuits).

TELEPHONES

A telephone receiver consists of a horseshoe permanent magnet round which are wound many turns of fine insulated copper wire. Close to the poles of the magnet is a thin iron disc or diaphragm, supported at its edges by the case of the receiver. Variation in magnetic force, caused by the changing electric currents through the

windings of the magnet, makes the diaphragm vibrate. These vibrations set the air in motion, producing sound waves of audible speech.

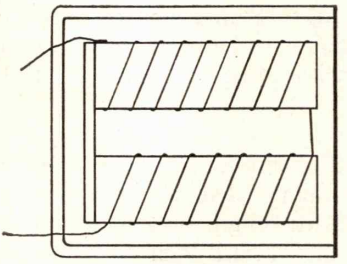


FIG 122. A telephone receiver.

The changing electric currents result from the effect of the sound waves of the speaker's voice beating against the diaphragm of the transmitter. Behind the diaphragm carbon granules are packed. The varying pressure of the diaphragm alters the tightness of the packing of the granules, and hence their electrical resistance. This changes the strength of the current passing through the microphone, and, of course, through the whole circuit.

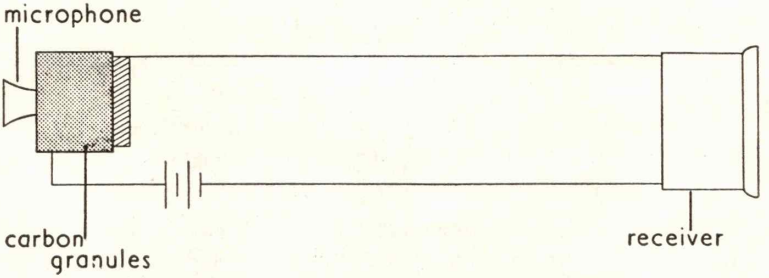


FIG. 123. A simple telephone circuit.

A simple telephone circuit is shown in *Fig. 123.* In actual practice the voltage of the microphone signals is stepped up by means of a transformer, about which you will learn something later.

A radio headphone is similar in construction to a telephone receiver, but since it must respond to much smaller currents, it is made more sensitive by means of many more turns of wire round the electro-magnets. Of course, the more wire, the greater the resistance. Good radio headphones have a resistance of up to 4000 ohms. Very small currents will produce audible sound in a radio receiver. If you

connect two pairs of headphones together—just connect the phone tips by wires—and get someone to speak into one pair, you will hear him in the other. A headphone can act as a transmitter because vibration of the diaphragm causes tiny electric currents to be set up in the electro-magnets.

The Electric Motor

An electric motor consists of an electro-magnet mounted so that it can rotate between the poles of a permanent magnet or another electro-magnet.

You have learned that a current passing through a wire sets up a magnetic field about it. If a wire passes through the magnetic field formed between the unlike poles of a couple of bar magnets and a current is sent through it, the magnetic field created will tend to make it move. The following experiment shows this effect.

EXPERIMENT *To show the direction in which a conductor carrying a current moves in a magnetic field.*

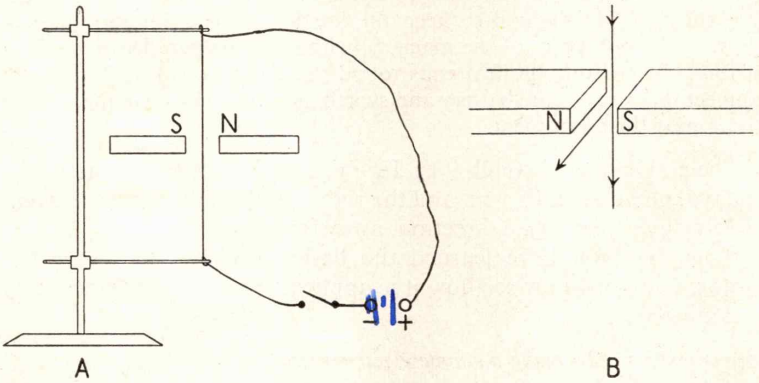


FIG. 124. Movement of a conductor in a magnetic field.

Attach two clamps to a retort stand and stretch loosely a piece of insulated copper wire between them (*Fig. 124*). Connect the ends of the wire to a 6-volt accumulator, including a switch in the circuit. (See footnote, p. 222.) Place a N pole of a bar magnet close to the middle of the wire, and a S pole directly opposite it. Retort stands can be used to hold them in position. Switch on the current for a short time. Reverse the battery connexions and repeat the experiment.

You will notice that the wire moves sharply when the switch is closed. It is deflected at right angles to the lines of force of the magnetic field, and to the direction of the current (*Fig. 124* B).

EXPERIMENT *Repeat the last experiment, using a closed coil of wire instead of a straight piece.* Fig. 125.

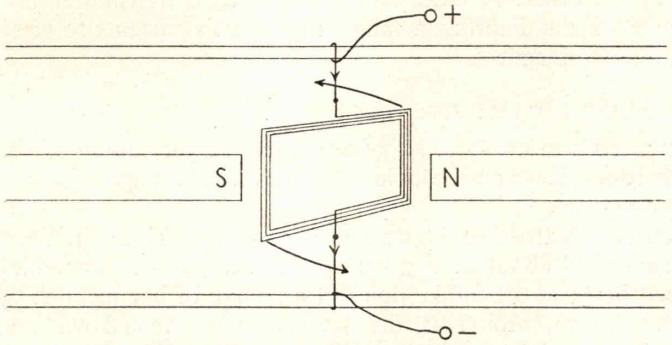


FIG. 125. Rotation of a coil of wire conducting a current when it is suspended in a magnetic field.

Wind a few turns of insulated wire into a rectangular coil, and twist the free ends around the coil to keep the loops together. Support the coil between the N-S poles of the magnets, with its plane parallel to the lines of force, by twisting the free ends round the clamps on the retort-stand, connect the wires to the battery and switch as before. Reverse the current and repeat the experiment.

The coil rotates through 90°. In *Fig. 125* the left-hand side of the coil will move towards you, and the right-hand side, since the current is flowing in the reverse direction, away from you.

Now that you have learned the basic principle of the electric motor, you must now see how it is applied. You can do this best by making one.

EXPERIMENT *To make a simple electric motor.*

Get a cork, and stick a pin in the centre of each end. Stick two more pins in one end along the diameter of the cork and about half-way between the centre and the edge. Push these two pins further in than the centre pin.

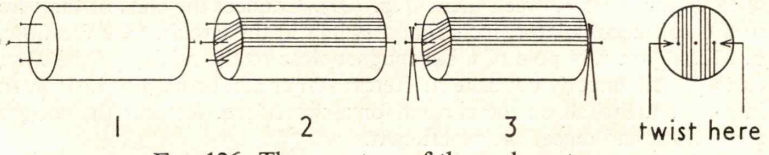


FIG. 126. The armature of the cork motor.

Bare the end of a length of insulated copper wire, twist it firmly round an outside pin, and wind evenly a layer of wire round the cork (*Fig. 126*).

When you have wound as far as the other outer pin, cut the wire, bare the end, and twist it firmly round the pin. Mount the cork on two pairs of crossed pins driven into a piece of cardboard as shown in *Fig. 126* (*3*). It should spin freely and evenly.

Place two bar magnets* on opposite sides of the cork, unlike poles facing each other. Take two six-inch lengths of copper wire—not too thick for it needs to be flexible—connect them to a battery. A dry cell will work a carefully-constructed motor. Now apply the two well-cleaned ends of the wires from the battery to the pins to which the ends of the wire have been twisted (*Fig. 127*). Each wire must touch one pin.

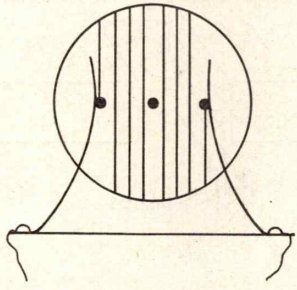


FIG. 127. The bared wires from the battery must make contact with the two outer pins.

If your motor does not start at once, it will show a tendency to move in one direction. That is the direction in which you should give it a spin in order to start it.

Do not be discouraged if it does not go at the first attempt. This is a thoroughly-tried little motor, and if it does not go, there is something wrong. Three likely faults are: (1) Your battery is flat; (2) the wires twisted round the pins are not actually touching them—they must make contact; (3) you have two like poles facing each other instead of a N and a S pole.

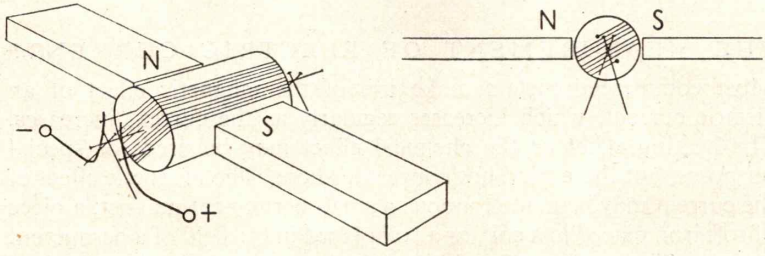


FIG. 128. The completed motor.

*A horseshoe magnet will do just as well.

You will observe that your motor has the following parts:

(1) *An armature*—the part that moves.

(2) *A commutator*—the two pins through which the current enters and leaves the coil.

(3) *The brushes*—by means of which the current is led to the commutator.

(4) *The field magnets*—which provide the magnetic field in which the armature rotates.

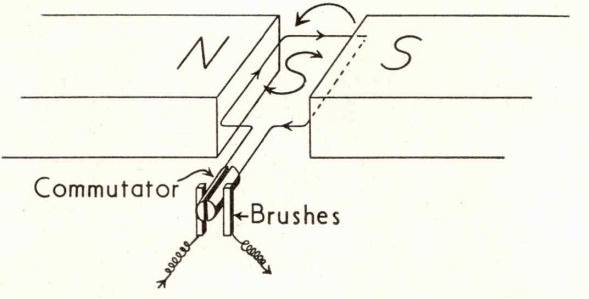


FIG. 129. The principle of the electric motor.

Study *Fig. 129.* When current flows through the loop of wire in a clockwise direction there will be a S pole facing you. Since the coil is free to move it turns in such a direction that this S pole will face the N pole of the field magnets. It does not stop in this position, however, but is carried on some distance by its own momentum. Now the current through the coil is reversed, since the split-ring or commutator is turning also; thus the coil gets another push in the same direction. By the attraction of unlike poles and the repulsion of like poles the armature continues spinning. To change its direction you would have to reverse the current.

THE MEASUREMENT OF ELECTRIC CURRENTS

Most commercial meters make use of the magnetic effect of an electric current, which increases regularly as the current increases. The heating effect or the chemical effect may be used for special purposes, but these need not concern us here. The magnetic effect of the current may be made to move a small permanent magnet, a piece of soft iron placed in a coil, or a coil placed in the field of a permanent magnet. Thus we have 'moving-magnet', 'moving-iron' and 'moving-coil' meters. Those used to measure current in amperes are called *ammeters;* voltmeters measure electrical pressure in volts.

1. The moving-magnet meter

This type is used in motor cars to show the rate of charge, or discharge, in amperes. Its construction is shown in *Fig. 130.*

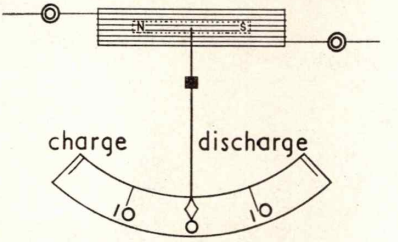


FIG. 130. Moving magnet ammeter.

One of the wires is connected directly to one terminal of the battery, the other to the main switch on the instrument panel. Current flowing from the dynamo to the battery is, of course, in reverse direction to current flowing from the battery. Hence the pointer moves to one side or the other according to the direction of the current flow, i.e. to 'charge' or 'discharge'. (See 'right-hand rule', p. 223.)

Meters of this type are suitable for direct current only (D.C.). The magnet could not move fast enough to keep pace with the changes of direction of alternating current. (See 'Alternating Current', p. 243.)

2. The moving-iron meter

Two bars of soft iron are placed inside a coil of insulated copper wire. One bar is attached to a lever terminating in a pointer; the other is fixed to the case of the instrument (*Fig. 131*). When a current passes through the coil, both bars become magnetized in the same way, N poles and also S poles being adjacent. Hence they repel each other, and the movable bar moves the pointer. The larger the current, the stronger is the induced magnetism in the bars and the greater the repulsion.

Generally the pointer is kept at zero by means of a small coiled spring.

In another type of moving-iron instrument there is a solenoid into which a small piece of soft iron is drawn when the current flows.

These instruments are suitable for either direct or alternating currents. The movable soft iron bar is repelled in the one type and the solenoid acts in the other, whichever way the current is flowing.

The scale on a moving-iron meter is not regularly spaced, the lower graduations being cramped closely together.

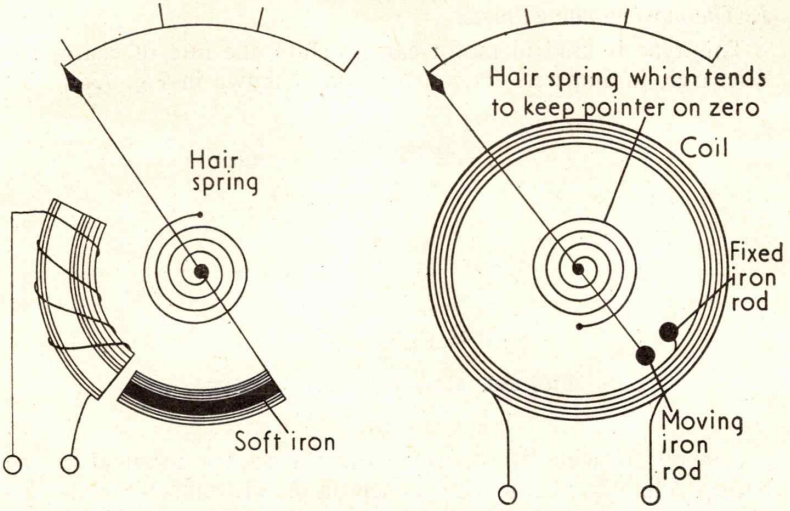


FIG. 131. Moving-iron meters showing the attraction and repulsion types.

3. The moving-coil meter

A coil of wire is pivoted between the poles of a powerful horseshoe magnet. It is kept in position with the pointer at zero by means of two pairs of hair-springs, one at the back and one at the front. These springs serve the added purpose of conducting the current into and away from the coil (*Fig. 132*).

When a current flows through the coil the induced magnetism causes it to rotate in the magnetic field in which it is placed, just as the armature of a motor rotates.

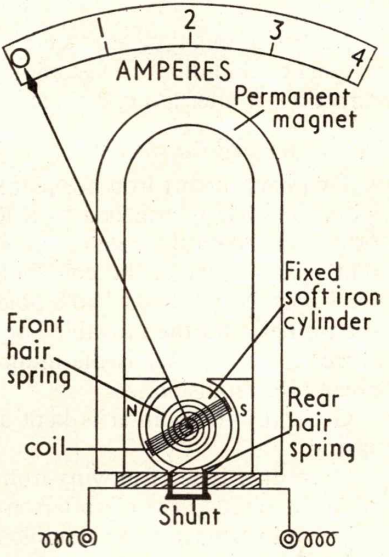


FIG. 132. Moving-coil meter.

Unlike the moving-iron meter, the moving-coil instrument has a scale that is regularly spaced. It cannot, however, be used for alternating currents, since a change in the direction of the current would

also change the direction of the movement of the coil. In fact, these instruments always have their positive terminals marked +, and it is essential that they be connected correctly—the positive wire to the + terminal.

How to Connect Voltmeters in a Circuit

A voltmeter is used to measure the electrical pressure of a battery (E.M.F.) or the voltage across the resistance (p.d.). In order to avoid waste of current, the resistance of a voltmeter must be kept as high as possible. You will see by examining the circuit of *Fig. 85* that a voltmeter of low resistance would affect appreciably the current flowing in the circuit.

Voltmeters are always connected in parallel with any resistance or battery. Their range may be extended by use of a series resistance. For instance, a voltmeter reading 0 - 1 volts can be used to read 0 - 10 volts by connecting to it a suitable resistance in series. In such a case, the scale reading is multiplied by a factor: in this particular example, a factor of 10 (*Fig. 133* A).

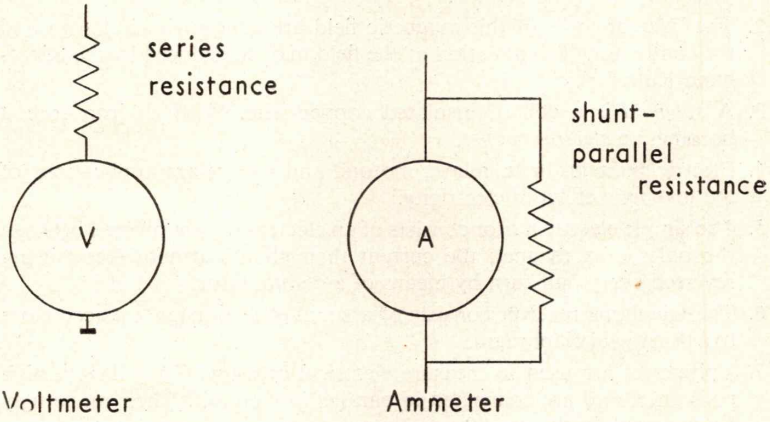


FIG. 133. Method of extending the range of (a) voltmeter, (b) ammeter.

How to Connect an Ammeter in a Circuit

Since an ammeter is used to measure the current in amperes flowing through a circuit, it must be connected in series with it (see *Fig. 85*). Its resistance must be low, otherwise it would considerably reduce the current it is intended to measure.

The range of an ammeter may be extended by means of a *shunt*, a wire of low resistance connected in parallel with it (*Fig. 133* B).

Some of the current passes through the shunt, only a fraction of the total current passing through the meter itself. Thus, an ammeter measuring 0 - 1 ampere could be used to measure 0 - 10 amperes with a suitable shunt to by-pass the extra current.

	METER	RESISTANCE	HOW CONNECTED	RANGE EXTENDED
Pressure	Voltmeter	High	In parallel	Series resistance
Current	Ammeter	Low	In series	Shunt

The Galvanometer is a very sensitive meter used chiefly to detect very small currents. It is fitted with a scale of the 'centre Zero' type, so that a change in the direction of a current can be detected.

SUMMARY

1. An electric current flowing through a conductor produces a magnetic field about that conductor.
2. The lines of force of this magnetic field are concentric circles around the conductor. The direction of the field may be deduced by the Right-hand Rule.
3. A *solenoid* is a coil of insulated copper wire. With an iron core it becomes an *electro-magnet*.
4. Electric buzzers, bells, relays, motors, and meters are applications of the magnetic effect of electricity.
5. The simple electric motor consists of an electro-magnet pivoted between the poles of a magnet, the current through the armature coil being reversed every half-turn by means of a commutator.
6. The telephone receiver consists of a small electro-magnet placed close to a thin metal diaphragm.
7. Voltmeters are used to measure electrical pressure. They have a high resistance, and are connected in parallel in a circuit. Their range may be extended by the use of a series resistance.
8. Ammeters are used to measure the current flowing in a circuit. To do this they are connected in series with it. They must have a low resistance. Their range may be extended by the use of shunts of low resistance.
9. There are three types of meters in common use.
   (a) Moving-magnet: a small permanent magnet pivoted in a fixed coil.
   (b) Moving-iron: a fixed and a movable rod of soft iron inside a solenoid.
   (c) Moving-coil: a small coil pivoted between the poles of a permanent magnet. The terminal to be connected to the positive wire is marked +.

20

Electromagnetic Induction

WE HAVE SEEN how magnetism is created by electricity. Can electricity be created by magnetism? This question was answered in 1831 by Michael Faraday, to whom goes the honour of being the first to demonstrate that a magnetic field applied near a wire sets up or 'induces' a current in it.

EXPERIMENT *To illustrate electro-magnetic induction.*

For this experiment you require a coil consisting of a large number of turns of insulated copper wire, a centre zero galvanometer, and a permanent magnet.

Connect the terminals of the coil to the galvanometer, and thrust one end of the magnet into the coil. Withdraw the magnet.

Take careful note of the following facts:

1. A current is induced only when the magnet is moving.
2. The current induced when the magnet is withdrawn is opposite in direction to the current induced when the magnet is inserted in the coil.

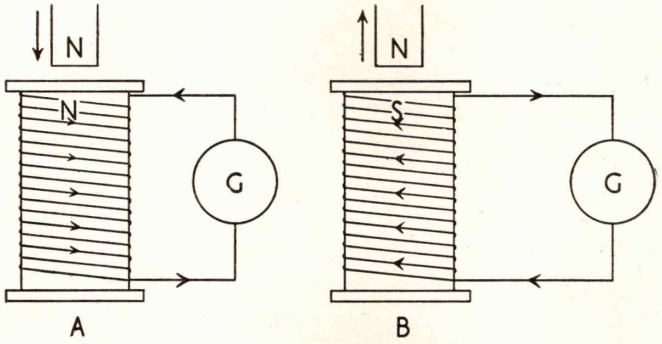


FIG. 134. Electromagnetic induction: (A) Magnet plunged into the coil; (B) Magnet withdrawn from the coil.

3. The direction of the current produced by inserting a N pole is opposite to that produced by inserting a S pole.
4. The magnitude of the current increases with the speed of the movement of the magnet.

When the N pole of a magnet is brought up to a coil, the current induced in the coil is such as to create a N pole opposite the end of the magnet (*Fig. 134* A). Were this not so, i.e. if a S pole was set up opposite to the N pole of the magnet, the magnet would be attracted to the coil, and we would be getting energy for nothing. The direction of the induced current is such that it tends to oppose the motion or change to which it is due. This is known as Lenz's Law. When the N pole of the magnet is withdrawn from the coil, the current induced is in such a direction as to create a S pole to try to stop the movement of the N pole. This explains why the direction of the currents induced when the N pole is inserted in the coil and when it is withdrawn are opposite in direction.

EXPERIMENT *To illustrate the principle of the induction coil.*

This experiment is similar to the previous one. Instead of a moving permanent magnet, a smaller coil is placed inside the coil which is connected to the galvanometer (*Fig. 135*).

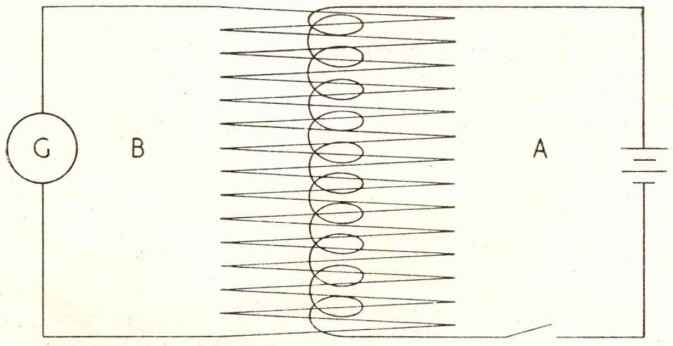


FIG. 135. Principle of an induction coil.

This smaller, or *primary* coil is connected with a switch and dry cell. When the current is switched on the galvanometer pointer 'kicks' in one direction and immediately returns to zero. Then, when the switch is opened, the galvanometer pointer 'kicks' in the opposite

direction and again returns to zero. The reason for this is that it is only when the current is building up to its maximum strength or decreasing again that a current is induced in the outer or *secondary* coil. Only a changing magnetic field induces a current in a conductor.

The Induction Coil

An induction coil produces high-voltage pulsating direct current from low-voltage direct current. The direct circuit through the primary coil must be interrupted rapidly, for if it were to flow steadily no voltage would be induced in the secondary. These rapid interruptions are achieved by means of a 'contact-breaker' which is similar to that of the electric bell.

The secondary coil is wound with thousands of turns of very fine gauge insulated wire (see *Fig. 136*).

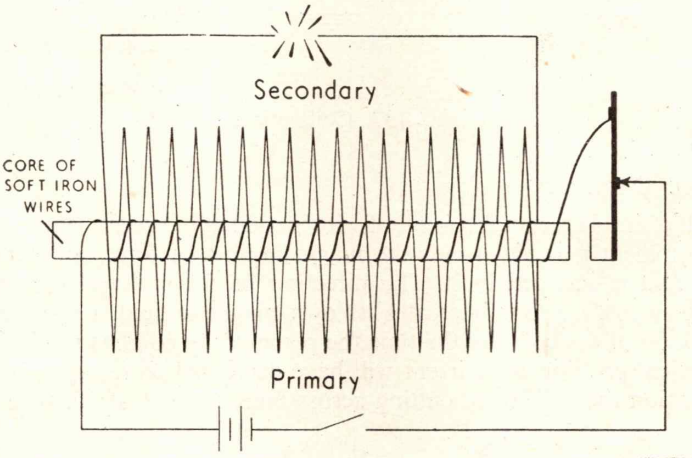


FIG. 136. The induction coil.

Induction coils are sometimes used as 'shocking coils'*, but their most important use is for motor car ignition. A very high voltage is needed to make a spark jump the gaps in the spark plug points at the required moment and thus ignite the compressed petrol and air mixture in the cylinders. The timing of this spark is achieved by having the contact breaker in the distributor mounted on the engine and driven by it. At the right moment the 'points' in the contact breaker are separated by a revolving cam, the distributor conducts the induced current to the correct cylinder, and the mixture is exploded. Since this high-tension current is at a voltage of the order of 10,000 volts, the cable conducting it must be exceedingly well

*It is dangerous to take a shock from a coil of any size.

insulated. If you examine a piece of high-tension ignition cable you will notice the thickness of the rubber covering. It is easy to understand, too, why the engine will not fire when the spark plugs are at all damp.

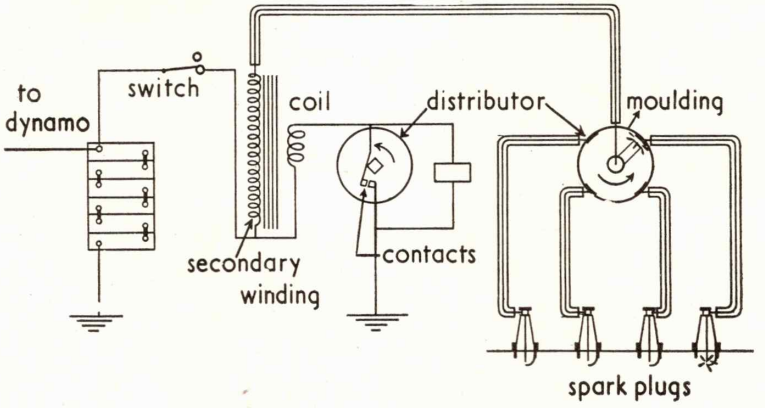


FIG. 137. Coil ignition.

THE DYNAMO

If a simple rectangular coil of wire is rotated between the poles of a permanent magnet, it cuts the magnetic lines of force and hence a current is induced in it. The direction of this induced current is shown in *Fig. 138:* it creates its own magnetic field to *oppose* the motion of the coil. By the time the plane of the coil has reached the vertical position the current will have decreased to zero, for in this position the coil is not cutting across lines of force at all. Then, as

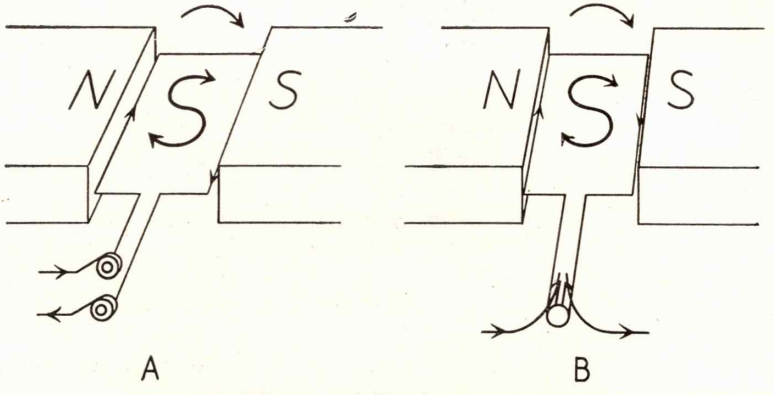


FIG. 138. The dynamo: (A) Alternating current; (B) Direct current.

the coil continues its rotation, the current increases again *in the opposite direction*, reaching its maximum when the coil is in the horizontal position, since it is then cutting the lines of force most rapidly (*Fig. 139*).

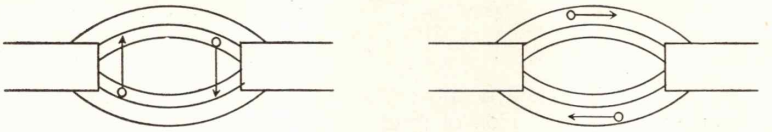


FIG. 139. Cross-section of a coil rotating in a magnetic field.

This current, therefore, is not a steady one, but varies in both magnitude and direction twice in one revolution of the coil. This may be shown graphically as in *Fig. 140*. Such a current is known as alternating current (A.C.).

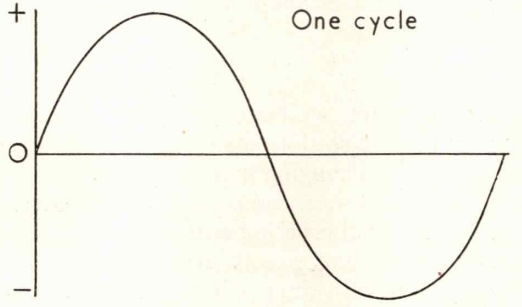


FIG. 140. Graphic representation of one 'cycle' showing the changes in the strength and direction of the current.

The number of cycles per second is called the frequency of the alternating current. The frequency of the alternating current supplied to our homes is 50 cycles per second—so fast that we do not notice any flicker in our electric lights.

The alternating current induced in the coil is collected by means of *slip rings* to which the ends of the coil are attached, carbon brushes pressing against them to lead the current in and out (*Fig. 138* A).

Direct current* is obtained by fastening the ends of the coil to a *commutator*, consisting of a split ring, as in the motor. Since the commutator rotates with the coil, current always flows in at the same brush, and out at the other (*Fig. 138*B).

In practice, dynamos have many coils, and commutators of many segments, so that a very steady current is obtained.

*Direct current (D.C) flows continuously in one direction.

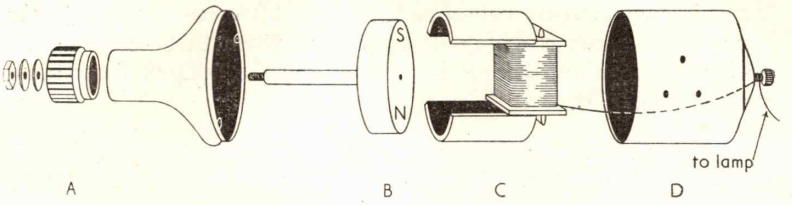


FIG. 141. A bicycle generator: (A) Friction drive; (B) Permanent magnet rotor; (C) Coil of insulated wire wound on iron core; (D) Terminal, insulated from metal cover.

THE BICYCLE DYNAMO

This is a simple generator in which a permanent magnet is rotated between coils of wire, thus inducing an alternating current in the coils. One end of the coil is connected to the metal framework of the bicycle, the other end to one terminal of the lamp. The circuit is completed by the contact made with the framework by the other lamp terminal.

THE TRANSFORMER*

An alternating current, we have seen, is a continually changing current, reversing its direction many times each second and so producing a constantly changing magnetic field.

A most important device, called the transformer, is used for changing the voltage of alternating current. It consists of a primary coil, a secondary coil, and a soft iron core (*Fig. 142*). The primary coil is supplied with alternating current: alternating current is induced in the secondary.

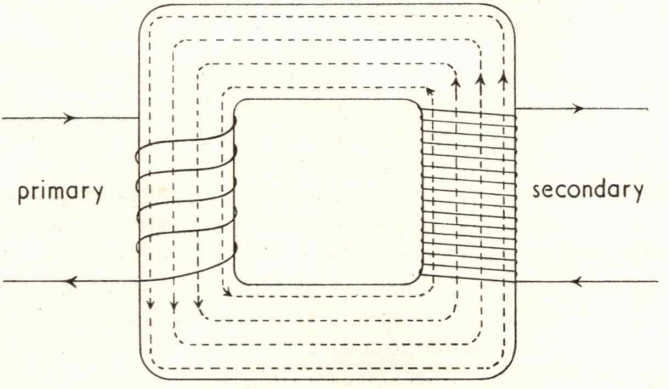


FIG. 142. A step-up transformer.

*Pupils should not do any experimental work with transformers. It is highly dangerous to do so.

If the secondary coil has twice as many turns of wire as the primary, the voltage induced in it is double that of the primary. The *power* remains the same, however, for the secondary *current* is only half the primary current. Actually there are certain losses as some of the electrical energy is wasted in heat. Hence, the 'output' current is less than half the 'input' or primary current. If we ignore these losses the following statement holds true:

Primary volts × *primary amps* = *secondary volts* × *secondary amps*

A transformer which is used to obtain an increased voltage is called a 'step-up' transformer. A 'step-down' transformer reduces the voltage: in this case the secondary coil has fewer turns than the primary.

A most important use of transformers is in connection with the distribution of electricity throughout the country. The voltage is stepped up to a very high level and stepped down by stages to much lower and safer values for final distribution to the homes (see *General Science*, p. 389). Transformers are used in radio sets, and for providing low voltage for bell-ringing.

SUMMARY

Whenever magnetic lines of force are cut by a conductor, an induced current is set up in the conductor. This is known as electro-magnetic induction.

It may be brought about by

(1) moving a magnet near a conductor,

(2) moving a conductor near a magnet (dynamo),

(3) starting, stopping, or changing the current in a nearby circuit (transformer and induction coil).

The direction of the induced current is such as to oppose the motion which caused it.

A transformer is used for stepping-up or stepping-down alternating current voltages.

Induction coils are used for motor car ignition systems.

The dynamo generates electricity by means of electro-magnetic induction. Coils of wire are rotated in a magnetic field, and D.C. is obtained by means of a commutator and carbon brushes.

21

Reflection of Light

IN YOUR EARLIER STUDIES you have learned that light is a form of energy. It travels in straight lines and is absorbed in varying degrees by the surfaces it meets. A highly polished surface reflects much of the light which strikes it: you have learned the laws which summarize the behaviour of light rays undergoing reflection.

THE LAWS OF REFLECTION

(*1*) *The incident ray, the normal and the reflected ray lie in the same plane.*

(*2*) *The angle of incidence is equal to the angle of reflection.*

NOTE: The normal is the perpendicular to the mirror at the point of incidence. The angle of incidence is the angle which the incident ray makes with the normal. The angle of reflection is the angle made by the reflected ray with the normal.

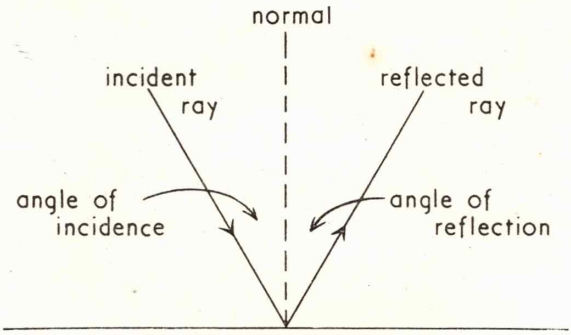


FIG. 143. Reflection at plane surfaces.

THE PLANE MIRROR

Here are the facts about a plane mirror you should remember. The image formed by a plane mirror is directly behind the mirror, as far behind the mirror as the object is in front of it, upright, laterally inverted, and virtual.

In *Fig. 144* the image I is directly behind the mirror (line OI is perpendicular to the mirror), and as far behind the mirror as object O is in front of it.

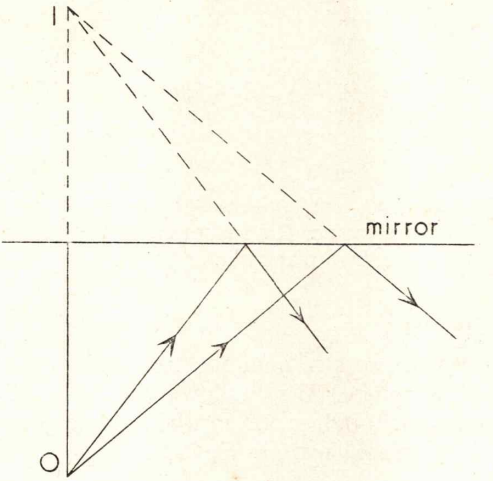
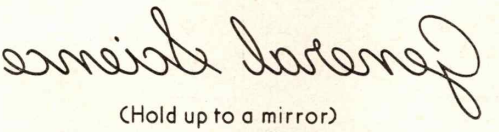


FIG. 144. The position of the image in a plane mirror.

What do we mean by a 'virtual image'? In *Fig. 144* you can see that there can be no actual image at point I at all, for light does not pass *through* the mirror. A *real* image can be thrown upon a screen, and when formed on the film in a camera produces a photograph.



(Hold up to a mirror)

FIG. 145. Lateral inversion.

The requirements for the formation of a real image are that the diverging rays of light from any particular point must be converged to meet at a point. A convex lens does this, whereas diverging rays of light continue to diverge after reflection from a plane mirror. Nevertheless, when we look in a plane mirror there *appears* to be an image. We call it a virtual image.

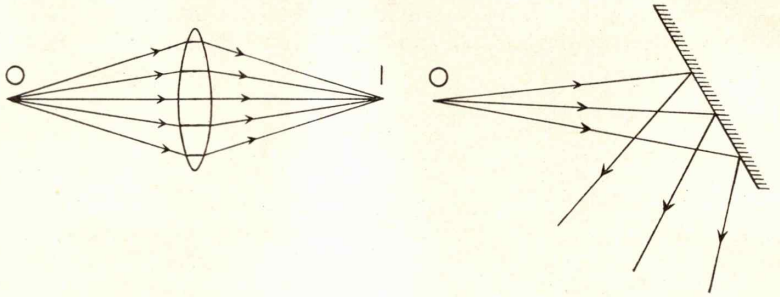


FIG. 146. The convex lens converges the rays to meet at a point, forming a real image. Rays from a point continue to diverge after reflection by a plane mirror.

CURVED MIRRORS

Other types of mirrors in common use are those whose surface forms part of a sphere. The 'hollow' ones are called 'concave' mirrors; those which bulge out in the middle are the 'convex' mirrors. Both types are shown in *Fig. 147.*

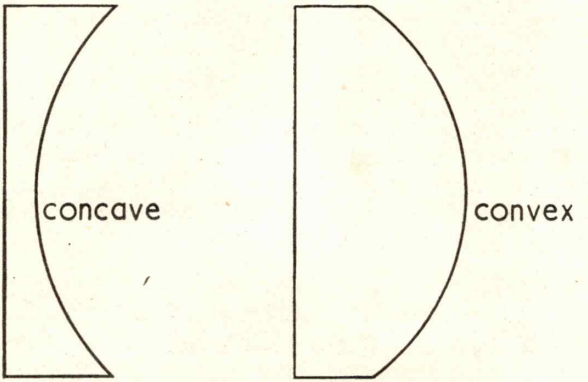


FIG. 147. Concave and convex mirrors.

These curved or 'spherical' mirrors are like plane mirrors in that the same laws of reflection apply, but they are markedly different in the effects they produce.

A *concave mirror* gives a magnified image if you are close to it, as, for example, when it is used as a shaving mirror. It is also quite capable of producing a *real* image, but the real image is always upside-down!

A *convex mirror* produces an image which is diminished in size, and so gives a wider field of view when used as a rear-vision mirror on motor cars. Of course the image is always the right way up!

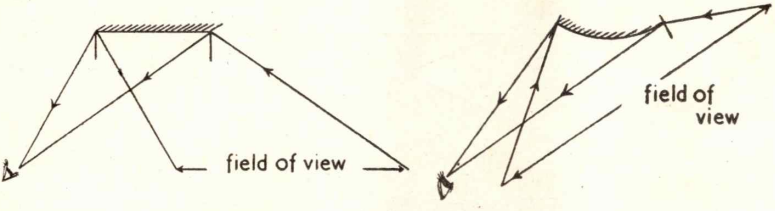


FIG. 148. A convex mirror gives a wider field of view than a plane mirror. Remember that the image in the convex mirror is diminished in size, and that vehicles approaching from the rear look further away than they really are.

Study *Fig. 149*. C marks the centre of the sphere of which the mirror is a part and is called the 'centre of curvature'. The straight line drawn through C to the centre of the mirror is called the principal axis. In (a) a ray of light AO, parallel to the principal axis, is shown meeting the mirror at O. The line CO is normal to the mirror surface, as is any ray passing through C. The angle of incidence AOC is equal to the angle of reflection COF. Thus the reflected ray OF passes through the point F. As shown in (b), all rays near to and parallel with the principal axis are reflected back through F. This point is known as the 'focal point' or 'principal focus'.

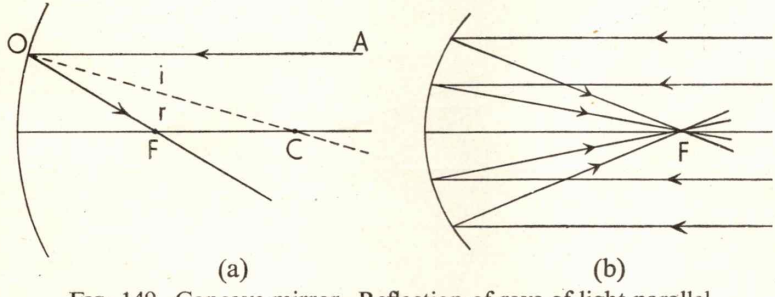


FIG. 149. Concave mirror. Reflection of rays of light parallel to the principal axis.

If you have a concave mirror, try the experiment of reflecting a distant scene on to a piece of paper. You will find you can obtain a sharp, clear image of the scene upside down. What *kind* of an image is this? *Fig. 150* shows how it happens.

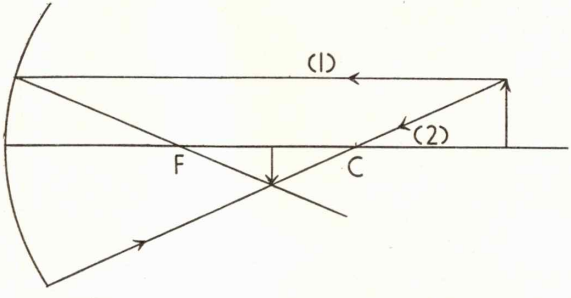


FIG. 150. When the object is placed beyond C, the centre of curvature, a concave mirror forms a real, inverted, diminished image.

The object—an arrow for simplicity—is placed some distance from the mirror. Two rays of light from the tip of the arrow are shown.

(1) parallel with the principal axis, is reflected back through point F.

(2) passes through C and so meets the mirror normally: it is reflected back along its own path. The two rays meet and a real image is formed at the point of intersection.

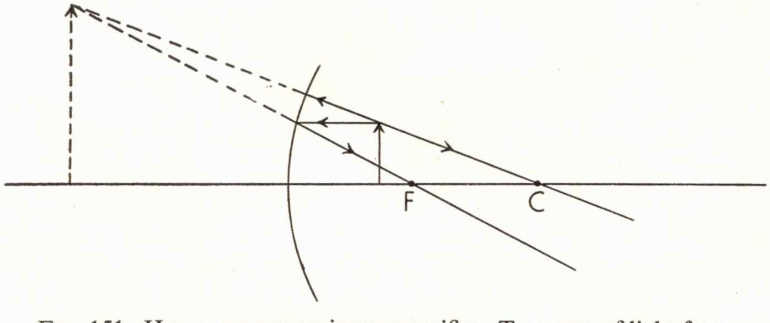


FIG. 151. How a concave mirror magnifies. Two rays of light from the tip of the arrow are shown: one, parallel with the principal axis, is reflected back through F; the other, along the normal, is reflected back along its own path. When these reflected rays enter the eye they appear to come from a point behind the mirror. The image, shown as an arrow in broken lines, is magnified, erect, and virtual.

Concave mirrors are widely used as reflectors in projectors and other instruments. They are so placed that the light source is at the focal point. Light which would otherwise be lost is reflected back where it is required. A more nearly parallel beam is obtained by using a reflector in the shape of a parabola: this type is used in motor car headlamps.

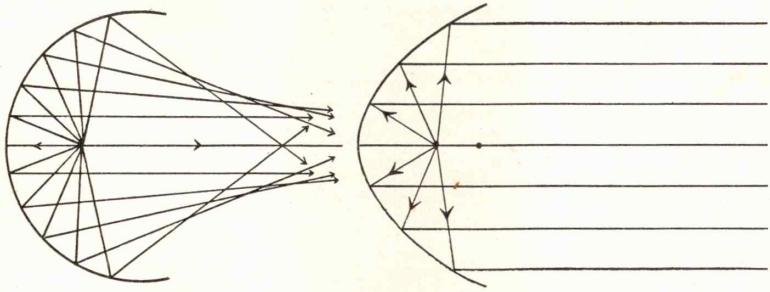


FIG. 152. Spherical and parabolic reflectors compared.

SUMMARY

1. Light is a form of energy, and may be transformed into other forms of energy.

2. The laws of reflection:
   (i) The reflected ray and the incident ray lie in the same plane.
   (ii) The angle of incidence is equal to the angle of reflection.

3. A *real* image is one that can be thrown upon a screen. A *virtual* image can be seen by the eye, but cannot be thrown upon a screen.

4. The image formed by a plane mirror is virtual; it is formed directly behind the mirror, as far behind the mirror as the object is in front of it. It is upright, and laterally inverted.

5. Parallel rays of light are reflected to converge through the principal focus in front of a concave mirror.

6. Concave mirrors give a real inverted image except when the object is closer to them than the principal focus, in which case the image is virtual, upright, and magnified. This latter property is made use of in shaving mirrors.

7. Convex mirrors always give a virtual, erect, diminished image. They are generally used for rear-vision mirrors in motor cars, as they give a wide angle of view.

22

Refraction of Light

A RAY OF LIGHT is bent or 'refracted' as it passes from one medium to another. It is bent towards the normal as it enters an optically denser medium, and bent away from the normal as it enters a medium which is less dense optically.

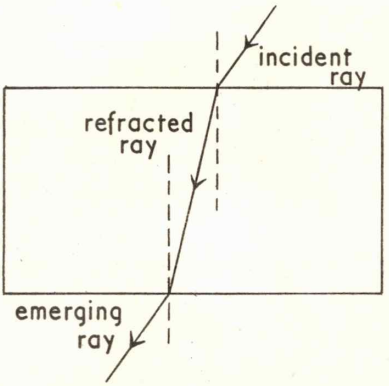


FIG. 153. Path of light through a block of glass.

In *Fig. 154*, let O be a source of light. A ray of light normal to the surface of the water will travel on without any bending. Another ray, OP, will be bent away from the normal in the direction PQ.

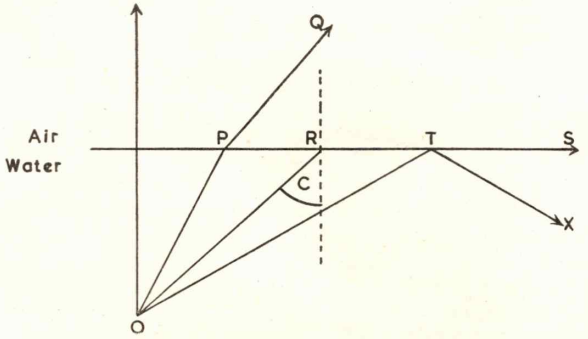


FIG. 154. Total internal reflection. C equals Critical angle.

Eventually, as the inclination to the normal is increased, a stage is reached when the emergent ray RS lies along the surface of the water. If the angle of incidence be increased still further, the ray cannot emerge from the water at all, and is totally internally reflected. See ray OT, which is reflected internally in the direction TX.

The *angle C* is known as the *critical angle*. The critical angle for water is about 48°; for glass it is about 42°.

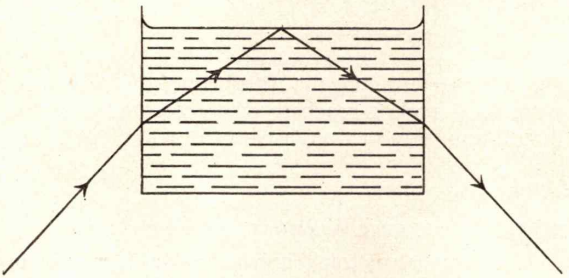


FIG. 155. Total internal reflection. The light strikes the under-surface of the water at an angle greater than the critical angle.

Total internal reflection is shown by using the glass tank filled with a fluorescent solution and shining a beam of light upwards at it so that the angle of incidence at the under surface of the water is greater than the critical angle (*Fig. 155*).

EXPERIMENT Hold an empty test-tube in a beaker of water as shown in the diagram, and looking down on it, observe the reflection of light from a window. Now fill the test-tube with water. Can you now see the reflected light as before?

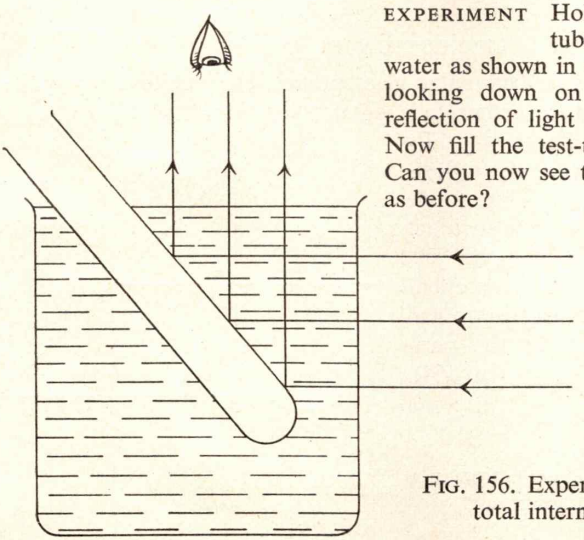


FIG. 156. Experiment illustrating total internal reflection.

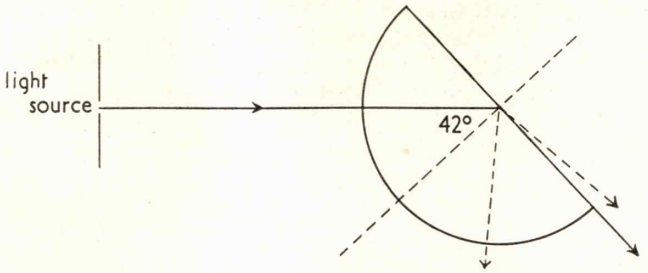


FIG. 157. Determining the critical angle for glass. Before the critical angle is reached some reflection takes place in addition to refraction, as shown by the dotted lines.

EXPERIMENT *To determine the critical angle for glass.*

Using a 'ray track' apparatus, the light is arranged to give a single beam of light incident to a semicircular block of glass which is placed on the turntable with its curved edge towards the light. Since the incident beam is always at right angles to the curved surface no refraction takes place here. When a straight-edge is at right angles to the light beam, no refraction takes place. From this position, slowly rotate the turntable, observing how the refracted ray is bent more and more from the normal until it lies along the edge of the glass. When this stage is reached, measure the angle between the incident beam and the normal. It will be found to be somewhere about 42°.

TOTAL INTERNAL REFLECTION IN PRISM

Fig. 158 shows a triangular glass prism. The incident ray makes an angle with the further face greater than the critical angle for glass (42°), and hence is totally internally reflected, the reflected ray making the same angle with the normal as the incident ray.

Such prisms make excellent mirrors, and are used in optical instruments such as the periscope, and binoculars (p. 264).

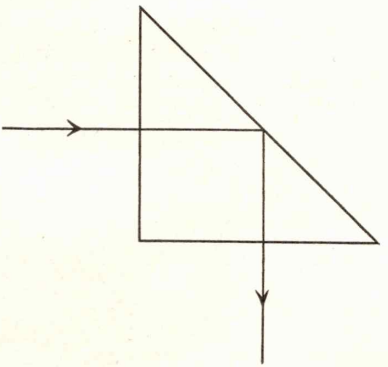


FIG. 158. Internal reflection in a triangular glass prism.

Have you noticed in your experiments on refraction that there is always some reflection from the refracting surface?

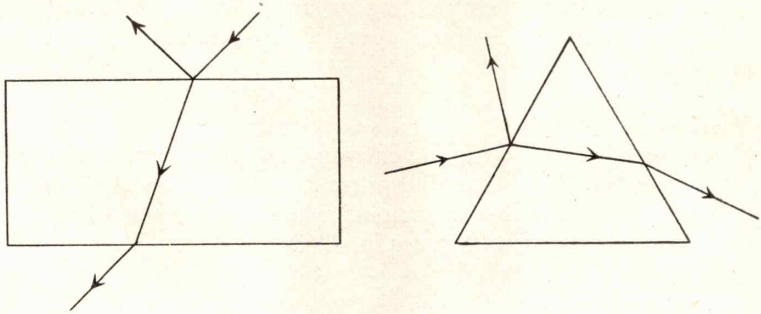


FIG. 159. Some light is always reflected from the glass surface.

THE GLASS PRISM

When a ray of light passes through a triangular glass prism it is bent or refracted in accordance with the laws of refraction (p. 252).

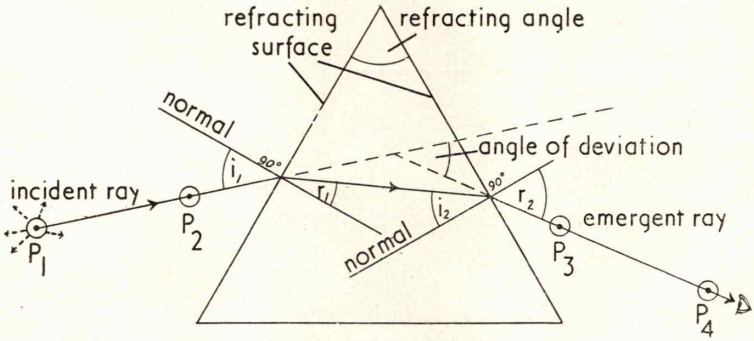


FIG. 160. The path of a ray of light through a triangular glass prism. The incident ray is marked by pins P_1 and P_2; the emergent ray by pins P_3 and P_4. When the eye is placed in the position shown, all four pins appear to be in line.

EXPERIMENT Use the ray track apparatus or ray box to project a ray of light on to a surface of a glass prism, the cross section of which is an equilateral triangle. Note the refracted beam and the emergent beam, also the beam of light reflected at the surface of the glass.

The path taken by the light passing through the prism is explained by the fact that as the light enters the glass it is bent *towards* the normal; as it passes from glass to air it is bent *away from* the normal.

The angle which the emergent ray makes with the incident ray is called the angle of deviation.

The angle between the refracting surfaces is called the refracting angle; the smaller the refracting angle, the smaller the angle of deviation.

Colour

In performing the last experiment you no doubt observed that the ray of light emerging from the prism is coloured. White light is dispersed into its component colours when it is passed through a glass prism. (See *General Science*, p. 424.)

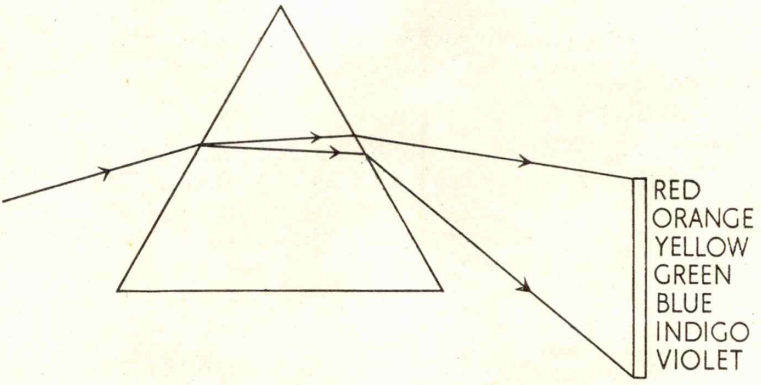


Fig. 161. The colour spectrum: White light dispersed into its component colours.

The order of the spectrum is easily remembered by the mnemonic 'Roy G Biv', or, if you find it easier, '*R*ichard *o*f *Y*ork *g*ave *b*attle *i*n *v*ain'.

The red end of the spectrum is deviated least (see *General Science*, pp. 424-5).

LENSES

You have all used lenses of one kind or another. With an ordinary hand lens you can magnify small objects or concentrate the sun's rays to burn holes in paper. The eye contains a lens which, if necessary, is corrected by wearing a suitable lens in front of it. Cameras, microscopes, telescopes, and projectors are all important applications of the uses of lenses.

Types of Lens

There are two main types of lenses:

(1) The convex or converging lens; they are thickest in the middle.

(2) The concave or diverging lens; thickest at the edges (see *General Science*, pp. 417-8).

Definitions (see *Fig. 162*)

The curved surfaces of a simple lens form parts of the surfaces of spheres.

The *principal axis* is the line joining the centres of curvature of the spherical surfaces of the lens.

The *optical centre* (O) of a lens lies on its principal axis, midway between the surfaces of the lens.

The *principal plane* is the plane perpendicular to the principal axis, passing through the optical centre.

The *aperture* (AB) of the lens is its width, or the diameter of the opening through which light passes. It is important to remember that the rules we shall be discussing apply only to lenses of small aperture.

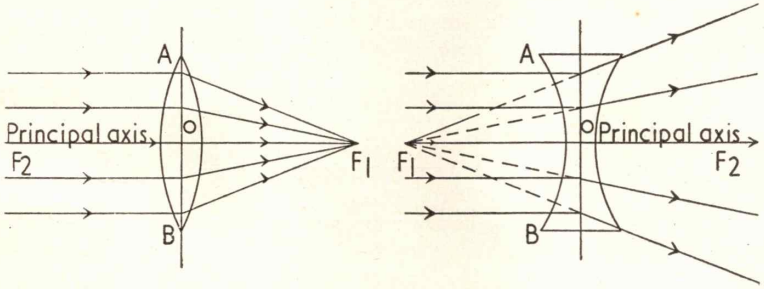


Fig. 162. (a) A converging lens; (b) A diverging lens.

In the case of the convex lens, parallel rays of light are converged by refraction to meet at a point F_1 (*Fig. 162*) called the *principal focus*. Since the light may be incident on either side of the lens, it has two principal foci, F_1 and F_2. The *focal length* of the lens is the distance from the optical centre to the principal focus.

Refraction of light rays as they pass through a concave lens results in a parallel beam being spread or diverged as is shown in *Fig. 162*. If the diverging rays are produced back they intersect at a point F_1, the principal focus.

For convenience, in *Figs.* 162 and 163 the rays of light are shown as bending at the principal plane only, whereas in fact bending takes

place as the rays enter and leave the lens (see *General Science*, pp. 417-8). The same procedure will be adopted in all your ray diagrams of lenses.

The main characteristic of a convex lens is its ability to converge rays of light, for it is thus enabled to form a real image. Rays of light from a certain point can be converged or brought to focus at another point behind the lens (see p. 248). It is in this way that a real image is formed.

EXPERIMENT *To determine the focal length of a convex lens.*

Method 1. Focus a distant object, e.g. window, on a white card. Measure the distance from the lens to the card: this distance is approximately the focal length of the lens.

Method 2. Using a ray-track apparatus, pass two parallel rays of light through a convex lens. Double convex cylindrical lenses are usually supplied with the ray-track apparatus for this purpose. The distance from the centre of the lens to the point at which the rays meet is the focal length of the lens.

Method 3. Using an optical bench. Cut a small triangle in a white card and then place this card, a lens, and a plane mirror in position as shown in *Fig. 163.* Now move the lens until a sharp image is formed alongside the triangle you cut in the card.

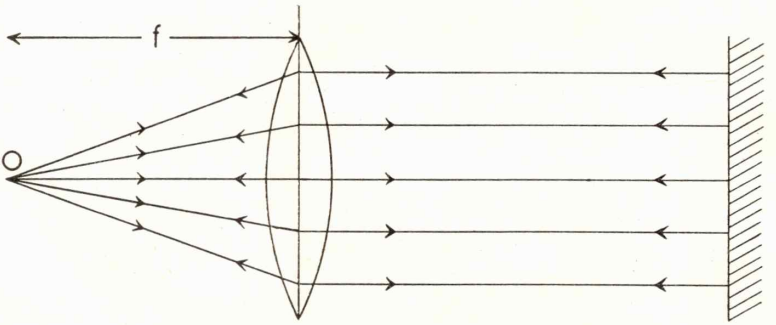


FIG. 163. Finding the focal length of a convex lens.

The illuminated triangle will now be at the focus, so that the rays passing through the lens will be parallel. As they strike the mirror normally, they will be reflected back along their own path giving an image which will practically coincide with the original triangle. Thus the focal length will be the distance from O to the optical centre of the lens.

EXPERIMENT *To study the images formed by a convex lens.*

You require an optical bench with a luminous object, a convex lens, and screen. Having first determined the focal length of the lens, now set it up with the object in the following positions:

(1) Object at a distance of more than twice the focal length of the lens.

(2) Object at twice the focal length of the lens.

(3) Object situated between 2f and f.

(4) Object closer to the lens than the focal point, i.e. principal focus.

In each case carefully measure the distance between the object and the lens, and between the lens and the image. Also make a note of the relative sizes of the object and the image.

In all the above instances you will note that the image thrown upon the screen is inverted. When you bring the object closer to the lens than the position 'f', however, you will find that you will try in vain to get any semblance of an image of the object on your screen. Merely *look* through the lens, and you will *see* the image. What do you notice about this image? What kind of an image do you think it is?

We find then that when an object is placed closer to a convex lens than its focal point, a virtual image is formed. It is upright and magnified. It is thus that a convex lens is used as a simple magnifying glass. *Fig. 164* shows how the image is formed.

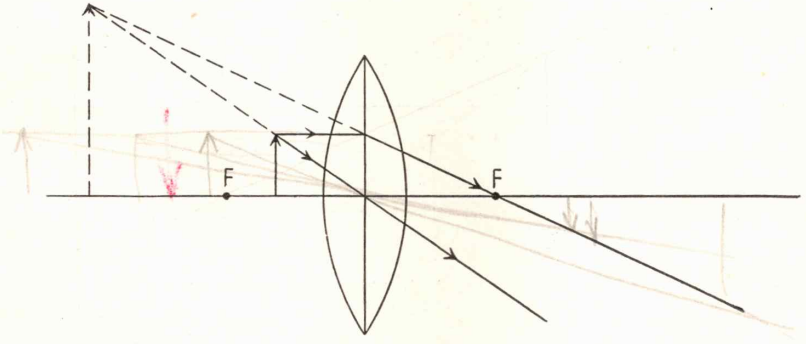


FIG. 164. A convex lens used as a simple magnifier. Two rays from the tip of the object arrow are shown. One, parallel with the principal axis, is bent to pass through F. The other, passing through the optical centre of the lens, is undeviated. Both rays *appear* to come from the tip of the image shown in the diagram (broken lines). The actual light rays are shown in full lines.

Let us summarize now the effects of placing a convex lens at various distances from an object:

POSITION OF OBJECT	POSITION OF IMAGE	NATURE AND SIZE OF IMAGE
Infinity	At f	real, inverted, diminished
Beyond 2f	Between f and 2f	real, inverted, diminished
At 2f	At 2f	real, inverted, same size
Between 2f and f	Beyond 2f	real, inverted, magnified
Closer than f	Beyond object, on same side of lens	virtual, erect, magnified

We began our experiments with the convex lens by focusing a distant object on a screen. The object could be said to be at 'infinity', and a sharp image was formed on a screen placed at the plane of the focal point of the lens. Now as the object moves in closer to the lens, the image (an inverted image, remember) moves slowly further away from the lens. When the object is just twice the focal length away, the image is the same distance from the lens and has now grown to be the same size as the object. As the object moves closer still to the lens, the image moves further away, increasing in size all the time. Now the object reaches the focal point. So far all the images formed have been real and inverted; but when the object is closer to the lens than 'f' the images formed are virtual, upright, and enlarged.

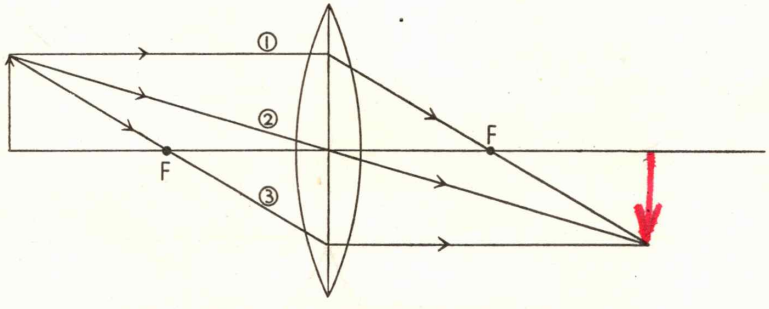


FIG. 165. Rays used in drawing lens diagrams.

HOW TO DRAW RAY DIAGRAMS

You will have no difficulty in drawing light ray diagrams showing the behaviour of the convex lens if you remember two simple rules. They are:

(1) A ray parallel to the principal axis is bent by the lens and passes through the principal focus (*Fig. 165*, ray 1).

It follows from this rule that if the incident ray passes through the principal focus it will emerge from the lens to travel parallel with the principal axis (*Fig. 165, ray 3*). In other words, if a ray can travel in a certain direction along a particular path, it can also travel along the same path in the reverse direction.

(2) A ray passing through the optical centre of the lens is undeviated. At this point in the lens we may regard it as a thin parallel slab of glass which does not bend the ray of light at all (*Fig. 165*, ray 2).

Magnification

No doubt you would notice in your experiments that there is a direct relation between the size of an image and its distance from the lens: the closer to the lens the smaller the image. The magnification depends upon the relative distances of object and image from the lens. If they are the same distance from the lens, they are the same size: we say the magnification is 1. If the image is twice as far from the lens as the object, the magnification is 2, for it is twice the size of the object.

$$\textit{magnification} = \frac{\textit{height of image}}{\textit{height of object}} = \frac{\textit{image distance}}{\textit{object distance}}$$

Problems on Lenses

Simple problems on lenses may be solved by the method of graphical construction. The best way to proceed is as follows:

(1) Make a small sketch of the ray diagram required.

(2) Decide on a suitable scale. Use as large a scale as the size of your sheet of paper will permit.

(3) Proceed with the scale light ray diagram. Draw the principal axis first, representing the lens by a straight line drawn at right angles to it, and marking 'f' first of all. Enter on your diagram the data given in the problem.

Convex Lens: Examples of its Everyday Uses

1. The Camera

See *General Science*, p. 418, for diagram and description of the camera.

The diagram (*Fig. 166*) shows how a smaller stop increases the depth of focus, i.e. the ability of a camera to achieve reasonable sharpness over a wider range of distances. O is a point of light, and it is brought to a focus at point I. Suppose the film to be in the position shown. With the lens wide open, the image of O is a

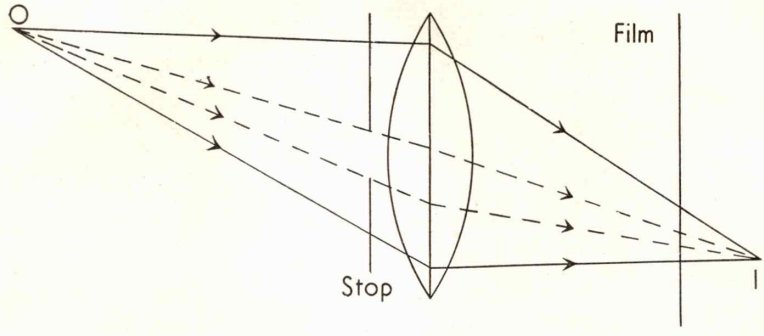


FIG. 166. A smaller stop gives a greater depth of focus.

circular dot—a blur. When a small stop is used this dot is considerably reduced in size (follow the dotted lines), and is small enough for acceptable sharpness. Actually, if it does not exceed one-hundredth of an inch in diameter the focus is sufficiently good for practical purposes. Definition or sharpness is of special importance in the case of miniature cameras as high degrees of enlargement are required.

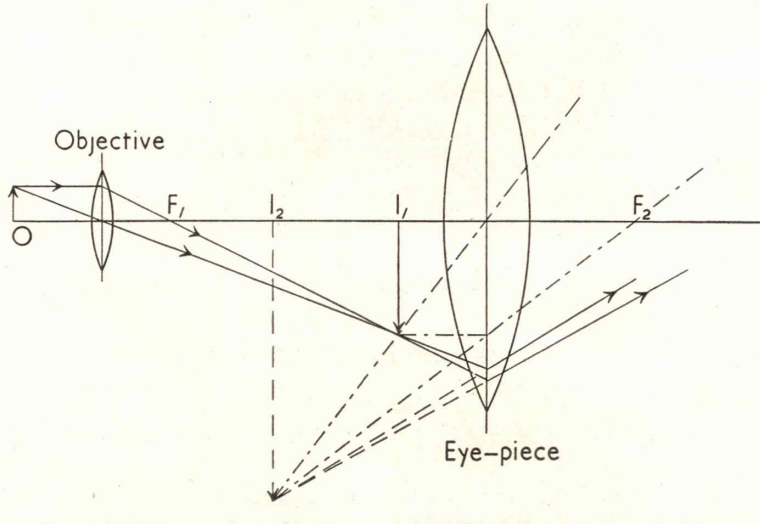


FIG. 167. The compound microscope. I_1 is the real image of object O formed by the objective lens. I_2 is the virtual image of I_1 formed by the eye-piece. You can try using two short-focus convex lenses as a compound microscope.

2. The Eye

The eye works in a manner similar to that of the camera. There is a lens at the front, an iris which opens up the pupil wide in poor light, and a sensitive retina upon which the images fall. Focusing in the eye is brought about by alterations in the convexity of the lens —not by movement of the lens as in the camera. The ciliary muscles change the shape of the lens of the eye (see *General Science*, p. 422).

3. The Microscope

You have already seen how the microscope in its simplest form —the magnifying glass—works.

The simplest form of compound microscope has two lenses, a short-focus convex objective, and a short-focus convex eyepiece. The real image given by the objective is magnified by the eyepiece to give an enlarged virtual image.

4. The Telescope

The simplest telescope consists of two convex lenses mounted in a light-proof tube of adjustable length. The objective (*Fig. 168*) forms a real image of the distant object, as large as possible. To this end the focal length of the objective must be large, and hence a long tube is required. The eyepiece, a convex lens of short focal length, magnifies the real image formed by the objective.

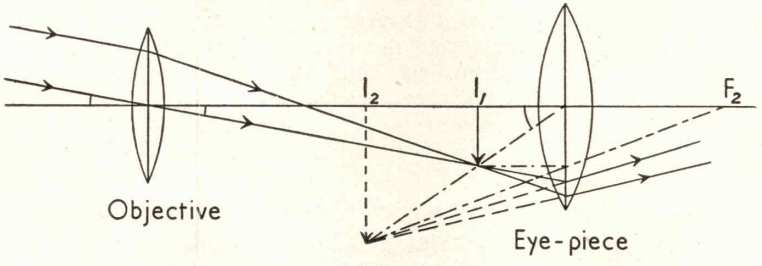


FIG. 168. An astronomical telescope. I_1 is the real image formed by the objective. This is magnified by the eye-piece to give virtual image I_2.

5. Prism Binoculars

We have seen that telescopes, by their very nature, must be long. Prism binoculars are an ingenious form of telescope without the shortcoming of inconvenient length. Study the cut-away diagram (*Fig. 169*) and see how the light entering the objectives is totally

internally reflected by two prisms, thus effecting a considerable saving of length. Moreover, after all this reflection the image is seen without inversion of any kind. Can you see why?

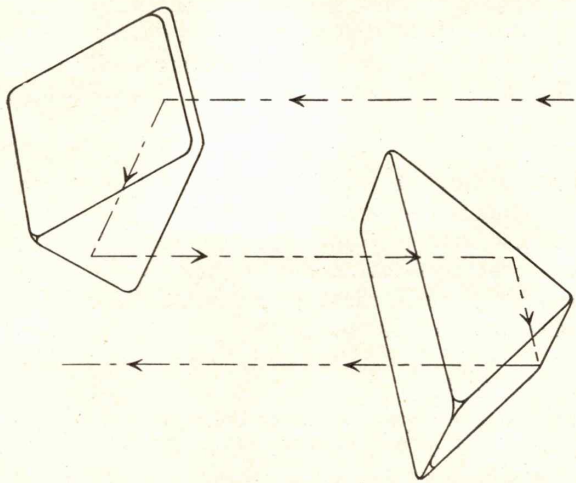


FIG. 169. The right-angled prisms in binoculars enable us to see an image which is neither upside down nor laterally inverted. The image formed by the objective lens is inverted longitudinally and laterally. The first prism, with hypotenuse face vertical, turns the image the right way up; the second prism, lying flat, rights the image laterally. You should try the effect of using two pocket mirrors held at right angles to each other.

If you examine a pair of binoculars you will notice they bear the figures '8 x 30' or similar figures. The '8' signifies the number of times magnification of the instrument; the '30' indicates the diameter of the objective lens in millimetres. Binoculars are manufactured mostly from 6x magnification to 12x. You will probably jump to the conclusion that it would be best to get a 12x instrument, but it is not quite as simple as that. The higher the magnification the more difficult it is to hold the instrument steady, or even to locate the distant object you wish to examine with your binoculars. It is generally agreed that a magnification of 8x or 9x is the most the average person can manage; higher magnifications require a firm stand, for every movement of the hand is magnified just as many times and the resulting image movement is intolerable.

The greater the diameter of the objective lenses the greater the amount of light admitted. Consequently it will be found that where the instrument is to be used mainly in poor lighting conditions, objectives of 40 mm or even 50 mm are necessary. Modern binoculars, in common with other optical instruments of today, have 'bloomed lenses' to minimize loss of light by reflection from lens surfaces.

SUMMARY

1. A ray of light is bent or 'refracted' as it passes from one medium into another of different optical density. This bending is caused by a change of velocity of light.

2. A ray of light passing from a denser to a rarer medium is bent away from the normal; if it makes an angle greater than the critical angle with the normal, it is totally internally reflected. Prism periscopes and binoculars make use of this phenomenon.

3. When a ray of white light passes through a triangular glass prism it is deviated, and also dispersed into its component colours, the longest wavelengths—red—being deviated least.

4. There are two main types of lenses. They are:

   (i) convex, or converging;

   (ii) concave, or diverging.

   Convex lenses are thickest in the middle; concave lenses have thick edges and are thinnest in the middle.

5. Parallel rays of light are converged to a point by a convex lens of small aperture. This point is known as the principal focus.

6. A convex lens produces a real, inverted image when the object is situated beyond the principal focus. When the lens is used as a simple magnifying glass the object is placed closer than the principal focus, giving a virtual, upright and enlarged image.

7. Some common applications of the use of convex lenses are:

   (a) the camera;

   (b) the eye;

   (c) the microscope;

   (d) the telescope;

   (e) prism binoculars.

EXERCISE

1. How would you determine the focal length of a convex lens?
2. Under what conditions does a convex lens give a virtual image? Is this image enlarged or diminished, upright or inverted?
3. An object 2 cm high is placed (*a*) 24 cm, (*b*) 16 cm, (*c*) 12 cm, (*d*) 6 cm, in front of a convex lens of focal length 8 cm. Find by accurate scale drawing the position, height and nature of the image formed in each case.
4. A miniature camera has a focal length of 50 mm. What is the distance between the film and the object when it is used to take a photograph the same size as the object?
5. A camera having a lens of 4 in. focal length is focused on an object 3 ft. away. What is the distance between lens and film?
6. An object 2 cm high is placed 9 cm away from a lens and a real inverted image whose height is 4 cm is formed. What kind of lens is it? What is its focal length?

23

Foods as Sources of the Food Constituents

IN YOUR EARLIER WORK, you learned that there are seven essential constituents of foods: namely, carbohydrates (starches and sugars), cellulose, fats and oils, proteins, water, mineral salts, and vitamins. We are now going to study the foods which make up our every-day diet, and find out which of these constituents each provides. The usual groups into which foods are divided are:

1. Milk, and milk products.
2. Meat, fish, and eggs.
3. Cereals.
4. Nuts and legumes.
5. Vegetables and fruits.
6. Sugar and fats other than butter.

(a) Milk and its Products

MILK

Milk is the fluid secreted by mammals for the feeding of their young. It occupies an almost unique place among animal foods since it contains the three nutritive constituents, protein, fat and carbohydrate, in significant amounts. (Avocado pears, nuts, soya beans and shellfish are the only other foods which do this.) Human milk is, of course, the natural food for the human infant; but milk is an important food at all ages, whether in sickness or in health, and in various parts of the world the milk of cows, goats, ewes, mares, and asses is a part of the staple diet of the people. Although cow's milk is the only kind used to any extent in New Zealand, the composition of the other types is given in the following table for comparative purposes. It should be realized that milk varies quite considerably in composition according to the breed of cow, the time of the year, and so on. It is a yellowish-white opaque liquid, containing substances in true solution, colloidal solution, and in suspension in water.

KIND OF MILK	WATER	PROTEIN	LACTOSE	FAT	ASH
Human	87·3	1·0	6·5	5·0	0·2
Cow	87·25	3·3	4·75	4·0	0·7
Goat	85·7	4·3	4·4	4·8	0·8
Mare	91·5	1·3	5·7	1·2	0·3
Ewe	80·8	6·5	4·9	6·9	0·9

The proteins of milk form about 3·3 per cent of its total weight. The chief proteins are caseinogen, which forms about four-fifths of the total, and lactalbumen. Caseinogen is a phosphorus-containing protein and lactalbumen coagulates on heating. When milk turns sour, the caseinogen is precipitated or thrown down in a flocculent form and the milk is said to have 'curdled'. When rennet* is added to milk, the caseinogen unites with some of the calcium salts in the milk and forms a solid clot called 'casein'. The exact change which takes place in this coagulation is not fully understood. These milk proteins are all of first quality and together have a very high biological value.†

The carbohydrate present in milk to the extent of nearly 5% is the complex sugar, lactose (a disaccharide), which is not sweet and not fermentable by yeast. It is, however, acted upon by lactic acid bacilli which are present in milk and which change it into lactic acid, a process which causes the souring of milk.

The fat of milk (usually called the 'butterfat'), present to the extent of 3·5% - 4%, is in the form of a very fine emulsion which is particularly easy to digest. It rises to the top when milk is allowed to stand and forms the 'cream', the remainder of the milk being called 'skim milk'.

The mineral matter, present in milk to the extent of 0·7%, is very varied in composition, but is particularly rich in salts of calcium and phosphorus. In fact milk is the main source of calcium in ordinary diets, the total amount of calcium in any given diet bearing a close relationship to the quantity of milk consumed by the individual. Milk is very low in iron. A newly-born animal has in its liver a store of iron which it has obtained from its mother's blood, but this store must soon be supplemented by foods containing iron (e.g. egg yolk). Nevertheless, the small amount of iron present in milk is in a form which is readily available in the body. Milk is remarkable, also, in containing an appreciable amount of citric acid (the acid in lemons) combined with calcium and magnesium.

*Rennet is an extract prepared from calves' stomachs and contains a ferment or enzyme called rennin.

†The 'biological value' of a protein is its power of replacing the protein of the body lost by wear and tear.

In addition, fresh milk contains vitamins A and D in the fat, and B factors and C in the watery part. Milk is quite a good source of riboflavin, but since riboflavin is destroyed by exposure to light, milk in bottles should not be left at the gate in bright sunlight or its riboflavin will be destroyed. This exposure to light causes a change in the taste of the milk, often erroneously put down to 'pasteurization'. When drawn from the cow, milk is slightly acid in reaction, and it gradually becomes more acidic on standing.

Though it is such an excellent food, milk has its dangers, chief of which is that it may transmit the germs of certain diseases to man, e.g. bovine tuberculosis, dysentery, typhoid fever, and summer diarrhoea. As will be explained later (see p. 271), this danger is guarded against—firstly, by pasteurization, and secondly by the long-term policy of eradication of tuberculosis from dairy herds and improved methods of hygiene in the production and distribution of milk.

Milk, taken as part of a mixed diet, is easily digested and well absorbed. Though sometimes referred to as a 'perfect food', it is not really so, but it has no equal in supplementing the deficiencies of other foods. As Rose, in *Foundations of Nutrition* says, milk 'regularly used in liberal quantities, forms the best possible foundation for an adequate diet'.

EXPERIMENT *To study the properties of milk.*

1. Examine the appearance.
2. Test the reaction to litmus.
3. Place a drop of milk on a slide and examine it under the microscope.
4. Dilute a small quantity of fresh milk with five times its volume of water. Add several drops of concentrated acetic acid, shake vigorously, and then filter.

(a) Wash the residue and test it*:

(i) for fat. Shake a little with ether, and then pour the ether on to a filter paper and let it dry. A greasy stain indicates the presence of fat.

(ii) For protein, by the Xanthoproteic test.

(b) Test the filtrate:

(i) for lactose, by Fehling's Solution test;

(ii) for protein, by Biuret test;

(iii) for phosphate;

(iv) for calcium.

*Descriptions of the usual tests are given in *General Science*, Chapters 18-21.

EXPERIMENT *To study the action of rennet on milk.*

1. To 30 cc fresh warm milk add about 10 drops of rennet and leave until a firm clot forms. Then break it up, pour into a filter paper to separate the curd from the whey.

(a) Test the curd for (i) fat,
(ii) protein.

(b) Test the whey
(i) for lactose;
(ii) for protein;
(iii) Heat a little, filter, and again test the filtrate for protein.
(iv) Concentrate the remainder of the filtrate to one-fifth of its volume and allow to crystallize. What will these crystals be?

2. To show that soluble calcium salts are necessary for the clotting of milk:

(a) Take a test-tubeful of warm milk and add a few drops of rennet. Keep warm in a water-bath at 36-40°C. Note that a clot soon forms.

(b) To a second test-tubeful of milk add a little ammonium or potassium oxalate solution and shake. Then add a few drops of rennet and keep warm as in (a). No clot forms.

(c) To the milk in (b) add 5-10 cc 5% calcium chloride solution and return to the water-bath. A clot now forms.

(*Explanation:* The addition of the ammonium or potassium oxalate throws the calcium salts out of solution and no clot forms. Then, after the addition of a soluble calcium salt, a clot forms; therefore the calcium salt is needed if clotting is to take place.)

Skim Milk

This is a valuable food, as only the fat of the milk (and with it the fat-soluble vitamins) has been taken from it. It is a very useful source of first-class protein, calcium, and riboflavin. It is, of course, not suitable as the sole food for infants; but it is a very useful addition to the ordinary diet of adults and children. Dried skim milk may be used in making bread, scones, cakes, etc. The percentage composition is given at the end of this chapter.

Cream

Cream, which rises to the top when milk is left standing, may be skimmed off, and then contains perhaps 20 per cent fat. If it is removed by centrifugal action (by a separator), it may contain as much as 65 per cent fat. Cream for sale must contain not less than 40 per cent fat, and nothing may be added to it. Protein and sugar

are also present in nearly as high amounts as in milk, the remainder being largely water. In fact, cream may be regarded as milk in which part of the water is replaced by fat. It is a palatable and easily-digested food, but is really a luxury. It is given in the diet in the case of sickness, to increase the intake of fat.

PASTEURIZATION

Pasteurization is a process of partial sterilization, named after the French scientist, Louis Pasteur, who invented it. It destroys micro-organisms that are killed by temperatures below the boiling-point of water, and is specially used for milk, though it may be used successfully with some other foods, e.g. fruit juices, ice cream.

Pasteurization of milk can be done in two ways:

(a) *Holding method:* Milk is heated to 145°F and held there for 30 minutes and then cooled quickly to 50°F or less.

(b) *Flash Method* (or High Temperature Short Time Method): Milk is heated to 162°F for 15-16 seconds and then cooled quickly to 50°F or less.

The method used depends on the type of installation. Both are equally effective if conditions of time and temperature are strictly adhered to. The latter method is the one used in the Wellington City Milk Department (see *Plate 9*).

Now, as milk contains all the food constituents (except cellulose), it is a perfect culture medium for bacteria (i.e. bacteria will grow and thrive in it). Hence milk, which is a very perishable food, should be produced, collected, and marketed under conditions of the strictest cleanliness and sanitation. Unfortunately, especially in large towns, where milk must be collected from many sources and transported long distances, it may easily pick up germs of various kinds and thus perhaps become a danger to health. The sources of contamination are:

(1) dirt collected during handling;

(2) tuberculosis in cows.

Dirt may be due to dirty shed conditions, dirty hands, dirty utensils, flies, contaminated water used for washing buckets, etc. In this way pathogenic germs (i.e. germs which cause disease in man) may get into the milk. Germs of such diseases as scarlet fever, typhoid fever, summer diarrhoea, undulant fever, epidemic sore throat, and bovine tuberculosis (see *General Science*, pp. 357-8) may thus be spread. Bovine tuberculosis is a form of tuberculosis which attacks bones, joints, and glands, and to which children are particularly susceptible.

If milk is pasteurized, the germs of all diseases known to be transmitted through milk to man, i.e. of the 'milk-borne diseases', are killed, and the milk is rendered 'safe'. That is why the use of pasteurized milk is so firmly advocated by health authorities. Pasteurization is not intended to take the place of sanitary production of clean milk, but until the causes of contamination can be tackled at their source and eliminated, it provides the final factor of safety from milk-borne diseases.

Pasteurization does not destroy the lactic acid bacilli which turn the milk sour, though it stops them from developing so rapidly. Pasteurization is thus not strictly a method of 'preservation' of milk. If the process is carefully carried out, the food value and taste of the milk are NOT altered. There may be destruction of vitamin C, but milk is not regarded as an important source of this vitamin anyway.

BUTTER

Cream is allowed to 'ripen' (i.e. to develop flavour) and sour slightly, by bacterial action, and is then churned or beaten until the globules of fat run together into semi-solid masses and a liquid called buttermilk separates from it. The buttermilk is run off and the butter washed and salted. Butter holds pride of place among the edible fats. It is the most palatable and digestible form of fat and is a rich source of vitamin A. Vitamin D is also present. Butter may contain not more than 16 per cent water (see *Plate 10*).

The colour of butter is usually due to carotenes and other yellow pigments in the food of the cows. The presence of water and of the protein caseinogen in butter, cause it to go rancid fairly quickly, as the caseinogen soon decomposes, and water aids this decomposition. Salt is generally added to check this. (Salt acts as a preservative, inhibiting the action of bacteria.) The flavour of butter is due to the growth of micro-organisms in the cream before churning. On a large scale, the cream is usually pasteurized and then ripened, with the production of some acid and the development of flavour and aroma, before churning. Butter may also be made from fresh cream.

Butter can be made to keep indefinitely by dehydrating it. The butter is melted, heated till the water evaporates, and then strained to remove the caseinogen.

CHEESE

Cheese is prepared from milk in two main ways:

(1) Raw or pasteurized milk is treated with rennet to produce a clot or curd.

(2) Pasteurized milk is soured by the addition of a bacterial culture called a 'starter', and is then clotted with rennet.

Method (1) gives a sweet curd and Method (2) an acid curd. Cheeses made from the latter have the better keeping qualities.

The milk used in cheesemaking may be (a) whole, (b) whole plus added cream, or (c) skim, and on this depends the richness of the product. The clot formed consists of casein in which any fat present is entangled, and it is usually ripened by the action of moulds and bacteria. After the curd has been fully formed, it is usually cut with special knives and this allows the whey to run out. The mass may be both stirred and warmed, and after the whey has run out sufficiently, it is cut into small pieces ('milled'), salted, and put into moulds. The remainder of the whey is then usually squeezed out under pressure, to give a hard cheese, e.g. Cheddar (the type usually made in New Zealand). If the whey drains out under the natural weight of the curd, a soft cheese results, e.g. Stilton. Soft cheeses still contain a little whey, and do not keep well, but hard cheeses are at their best perhaps a year after they are made. 'Processed cheese' is ordinary cheddar cheese to which not more than three per cent of a harmless emulsifying substance has been added. This gives it a different consistency from ordinary cheese. Such processed cheese is usually wrapped in tinfoil and sold in small packets. The flavours of particular kinds of cheese (of which there are a great many varieties that we do not see in New Zealand) are due to the action of special cultures of moulds and bacteria which grow in and on the cheese. (They are often specially added to it.) The changes are very complex and affect both the fat and protein. (See *Plates 11 & 12.*)

The nutritive value of cheese is very great. Cheese can be regarded as a method of making the valuable properties of milk last in a condensed form, long after the milk from which it is made would be unfit for consumption. Cheese made from whole milk is roughly one-third protein, one-third fat, and one-third water. The average percentage composition of New Zealand cheese (cheddar type) will be found in the table on p. 275. Besides being rich in the first-class protein, casein, and fat, cheese is a rich source of mineral matter, especially calcium salts, and contains vitamin A and riboflavin in fair amounts and smaller amounts of other B factors and vitamin D. It is a valuable food of high nutritive value which could well be used more in the New Zealand diet. Because it is concentrated (meat contains about 70 per cent water, but cheese only about 33 per cent), it is slow to digest, and the larger the lumps which reach the stomach the slower their digestion will be. Hence the importance of chewing it thoroughly. *Grated* cheese may safely be given to infants in small amounts from eighteen months of age or even earlier.

EXPERIMENT *To test cheese.*

(1) Find the percentage of water.

(2) Carry out the Xanthoproteic test for protein.

(3) Test for fat.

(4) Burn a small quantity and test the ash for the presence of calcium and phosphorus.

WHEY

Whey is the fluid which oozes from curdled or clotted milk on standing. We have seen already that the curd consists of the fat entangled in the casein, so the whey contains the lactalbumin, lactose, and some of the minerals and water-soluble vitamins originally present in the milk. It is a by-product of the cheese-making industry and is largely used in this country for pig-feeding. It is also the commercial source of lactose ('sugar of milk').

DRIED AND CONDENSED MILKS

Dried milks have had practically all the water removed from them by forcing the milk, either whole or skim, in the form of a fine spray into heated chambers, or as a thin film between heated rollers.

Condensed milks. Milk, either whole or skim, is heated at a low temperature under reduced pressure to remove part of the water. It may be left unsweetened or may have a considerable quantity (40 per cent) of cane sugar added to it.

These methods provide a means of preserving milk when it is in plentiful supply, for use when fresh milk cannot be obtained, e.g. by travellers, aboard ship, in isolated parts, and so on. The products can be transported easily, and enable New Zealand to export large quantities of milk to less-favoured countries. Dried and condensed milks when diluted in the right proportions with water, have practically the same food value as the milk from which they were made, the only differences being that any vitamin C present in the fresh milk has been destroyed, and the taste altered. These milks, when reconstituted, soon decompose. Sweetened condensed milk, on the other hand, when reconstituted, is NOT a substitute for fresh milk, particularly for the feeding of infants and young children, since it contains less protein, calcium, and riboflavin than the fresh product, and a very high proportion of added cane sugar. Such milk keeps quite well even after the tin is opened (the concentration of sugar retards the growth of bacteria), and has its uses in cooking when fresh milk cannot be obtained, and for sweetening tea.

Ice Cream

Ice cream varies considerably in composition, but has definite value as a food and is often used in cases of sickness to increase the intake of fat. It must contain not less than eight per cent fat. It is very palatable to most people. It is made from milk and cream or butter, and sugar. Sometimes eggs are added as well as fruit and fruit juices, and harmless flavouring and colouring substances. A small proportion of gelatine is usually added to stabilize the mixture. Ice cream which is to be sold commercially must be sterilized or pasteurized before being frozen.

The following table shows the percentage composition of milk and its products mentioned in this chapter:

PERCENTAGE COMPOSITION OF MILK AND MILK PRODUCTS

By Courtesy Massey Agricultural College

	WATER	PROTEIN	FAT	LACTOSE	ASH	ADDED SUBSTANCES
Milk	87·25	3·3	4·0	4·75	0·7	—
Cream	54·4	2·1	40·0	3·1	0·4	—
'Reduced' cream	68·1	2·6	25·0	3·8	0·5	—
Skim milk (separated)	90·55	3·45	0·08	5·1	0·82	—
Buttermilk	90·75	3·1	0·8	4·6	0·75	—
Whey	93·0	1·1	0·3	4·8	0·5	—
Condensed whole milk	73·6	6·6	8·2	10·0	1·6	—
Sweetened condensed milk	26·9	7·8	9·0	12·8	1·8	41·7*
Dried whole milk	3·0	27·1	27·3	36·6	6·0	—
Dried skim milk	3·9	37·4	1·4	49·1	8·2	—
Butter	15·9	1·0	81·6	trace	—	1·5†
Cheese (cheddar type)	35·5	25·2	33·5	—	4·0	1·8†
Ice cream	64·0	3·5	10·0	5·5	1·0	16·0‡

*Cane sugar. †Salt. ‡15 per cent cane sugar, 1 per cent gelatine, egg, etc.

SUMMARY

Milk. Contains first-class proteins, fat, carbohydrate, mineral matter, vitamins A, B factors, C, and D. Best food source of calcium. Palatable and easily digested.

Skim Milk. A valuable food; contains first-class proteins, calcium, water-soluble vitamins, lactose.

Cream. Contains not less than 40 per cent fat, and other constituents in nearly same proportions as in milk. Palatable and easily digested form of fat.

Butter. Prepared by churning ripened and slightly soured raw or pasteurized cream. Most palatable and digestible form of fat. Rich source of vitamin A and also supplies some vitamin D. Must not contain more than 16 per cent water.

Cheese. Prepared by action of rennet on raw or pasteurized milk. Contains roughly one-third first-class protein, one-third fat, and one-third water. Rich source of calcium and vitamin A. Vitamin B factors and vitamin D are also present. Concentrated food but well digested if chewed thoroughly or grated.

Whey. Separated from the curd in cheesemaking. Contains lactalbumin, lactose, and some of the minerals and water-soluble vitamins of milk. Commercial source of lactose.

Dried and Condensed Milk. All or part of the water removed by evaporation. Sugar may be added. Unsweetened, when reconstituted, similar in value to milk from which made, except that vitamin C is lost and taste altered. Sweetened, may have 40 per cent cane sugar added so when reconstituted, is not a substitute for ordinary milk.

Ice Cream. Made from milk, cream or butter, and sugar. Eggs, fruit and fruit juices, harmless flavouring and colouring substances, may be added, as well as a small proportion of gelatine to stabilize the mixture. Made commercially, must be sterilized or pasteurized before being frozen, and must contain not less than 8 per cent fat.

EXERCISE

1. What are the seven essential constituents of foods? State very briefly the purpose of each in the body.
2. Into what groups are foods usually divided?
3. What is the name of the chief protein in milk, and what chemical element is specially important in its composition?
4. What is the 'skin' that forms on top of hot milk?
5. What is the action of lactic acid bacilli on milk?
6. Of what mineral salts is milk a particularly rich source?
7. Why should milk in bottles not be left in bright sunlight?
8. What is meant by the term 'milk-borne diseases'? Give three examples of such diseases.
9. Name three food constituents that are well supplied by skim milk.
10. Of what value is cream in the diet?
11. (*a*) What is the percentage of fat in cream of good average quality? (*b*) What percentage of water is there in butter?

12. Give an account of pasteurization and of its effects on milk.

13. What is the nutritive value of butter?

14. Give an account of the process of cheesemaking.

15. Discuss the nutritive value of cheese.

16. Has ice cream any value as a food?

17. Give a brief account of the preparation and value in the diet of (*a*) dried, and (*b*) condensed milk.

(b) Meat, Fish and Eggs

MEAT

MEAT IS THE FLESH or muscles of an animal killed for food. It consists chiefly of muscular tissue but also contains connective tissues and fat. If you examine a piece of boiled meat you will see that it can easily be divided up into long stringy fibres. If one of these is examined under the microscope it will be found, in its turn, to be made up of a large number of smaller fibres—the muscle fibres. Now these bundles of fibres vary in length in different kinds of meat, and the shorter they are the more tender is the meat and the more easily is it digested. Meat should always be cut or carved 'across the grain' (i.e. at right angles to the bundles of fibres). It is then more easily chewed and the contents of the muscle fibres or tubes are exposed, thus increasing flavour and making digestion easier. These muscle fibres are bound together by connective tissue which contains the protein, collagen, which yields gelatine on boiling. The muscle fibres themselves contain a mixture of proteins, salts, and extractives dissolved in water. The younger the animal, the more water its muscles contain and the lower its nutritive value (see *Plate 13*).

The chief protein of the muscle is myosin, while the proteins of blood are also present in meat. After the death of an animal the myosin coagulates and the condition known as 'rigor mortis' or death stiffening takes place. If meat in this condition is eaten, it is always very tough; therefore, it should be used before rigor mortis has taken place, or after it has passed off. If meat is allowed to hang for a time, it will be found to be much more tender due to changes which take place in the connective tissue. The fat of meat is present in the connective tissues which bind the fibres and bundles of fibres together, and is also deposited in layers round the muscles. Lean meat has less than one per cent fat, but as purchased, meat may contain as much as 30 per cent fat, and most of the cuts commonly used contain 20 per cent or more. The percentage composition of lean beef is: water 75·9, protein 20·0, fat 0·9, mineral matter 1·3,

and extractives 1·9. Comparison of these figures with those given below will show that as the fat increases the water decreases, and so the fuel value of the meat varies according to the amount of fat present. Fat increases the palatability of meat and helps to retain moisture in it during cooking. The minerals present in meat are chiefly salts of phosphorus, potassium and iron, and a little copper. Its calcium content is low. Extractives give flavour but add nothing to the nutritive value of meat. The characteristic flavours of the different kinds of meat are due to the amount and kind of extractives present.

Meat is the main source of first-class protein in the New Zealand diet. We are relatively high meat-eaters, which is probably due in part at least to the abundance of meat and its former cheapness. Vitamin B factors are present in meat, especially pork, which is in particular a rich source of thiamine. The extractives, which are largely developed on cooking, make meat an appetizing and stimulating food. It is not, of course, a perfect food, as it lacks carbohydrates, vitamins A, D and C, and cellulose. Fat meat, especially when the fat is well mixed through the tissues, as in pork, takes longer to digest than lean meat. Meat is readily digested, and the products of digestion are well absorbed into the bloodstream. The average percentage composition of the commoner meats is given below.

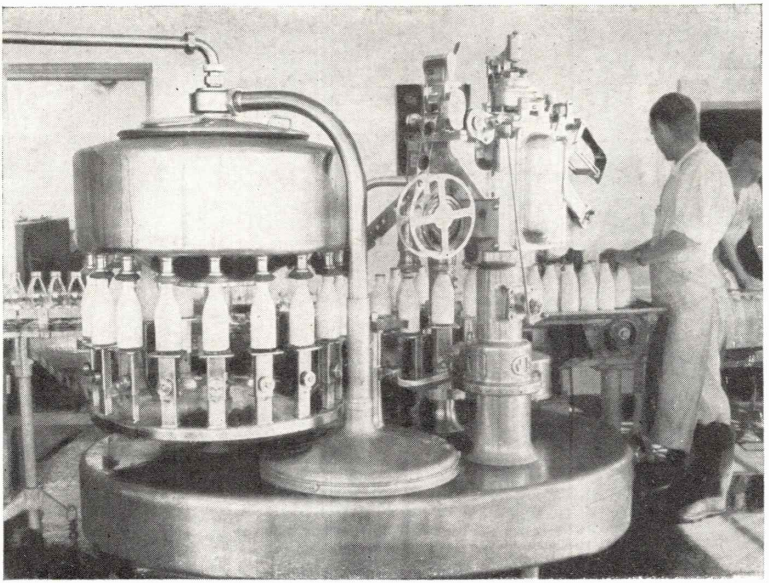
	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Beef	64·9	15·3	18·8	0·0	1·0
Veal	73·0	17·8	7·9	0·0	1·3
Mutton	53·1	14·2	31·5	0·0	1·2
Lamb	58·1	14·3	26·7	0·0	0·9
Pork	58·5	15·0	25·3	0·0	1·2
Poultry	71·3	19·3	8·3	0·0	1·1
Rabbit	72·3	20·3	6·2	0·0	1·2
Bacon: fat	43·5	19·0	35·0	0·0	2·5
Bacon: lean	61·5	19·0	17·0	0·0	2·5

EXPERIMENT *To test meat.*

1. Examine the appearance of raw meat.

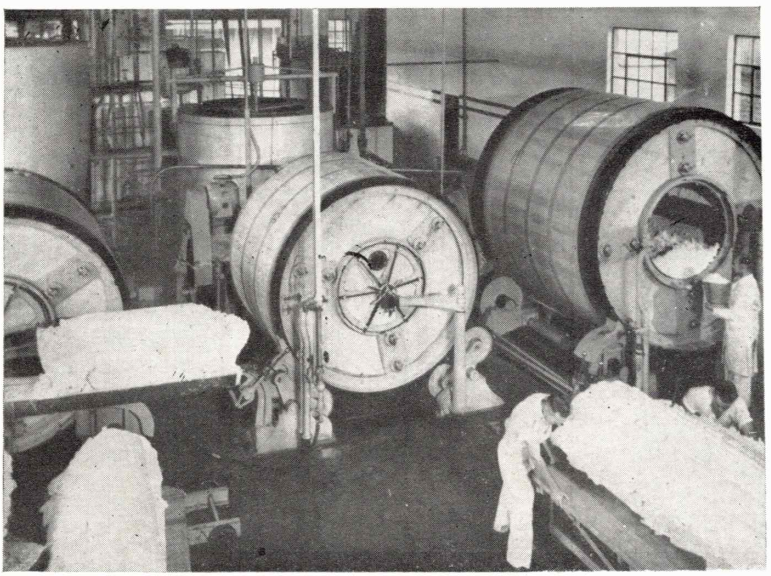
2. Test its reaction to moistened litmus papers (fresh meat should be acidic).

3. Mount a shred of raw meat on a microscope slide. Tease it out using two mounted needles, and examine it under the microscope.



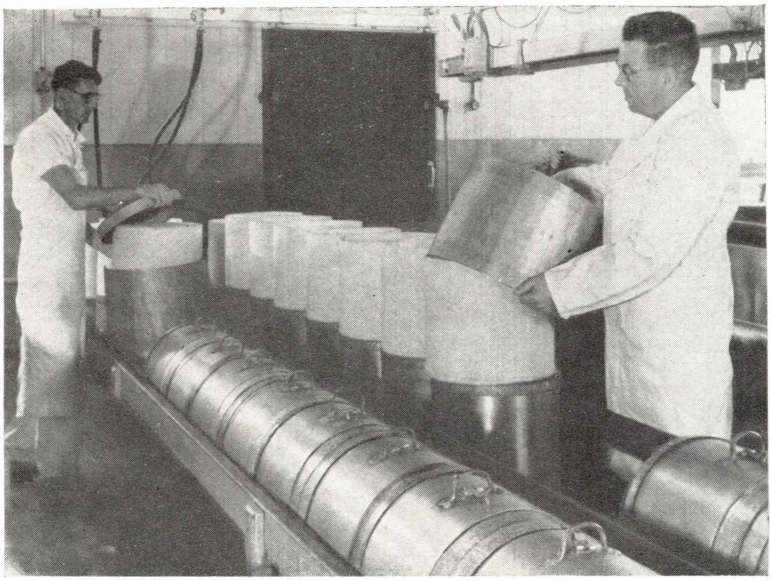
N.Z. DEPARTMENT OF AGRICULTURE

9. Bottling and capping pasteurized milk (Page 271)



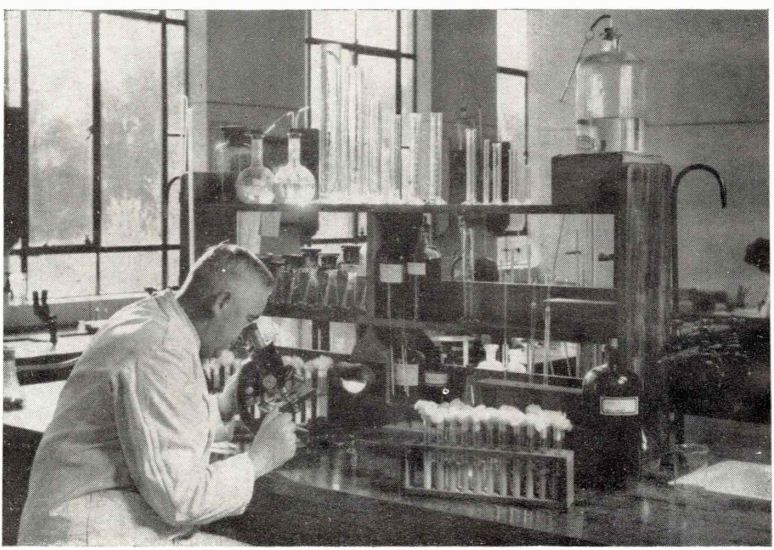
NATIONAL PUBLICITY STUDIOS

10. Butter-making in a New Zealand dairy factory (Page 272)



NATIONAL PUBLICITY STUDIOS

11. Pressing and packing cheese (Page 273)



NATIONAL PUBLICITY STUDIOS

12. Bacteriological examination of cheese for purity (Page 273)

4. Cut or mince up finely a piece of raw meat and soak it in cold water until the water is pink in colour. Pour off the liquid and note its appearance and that of the residue of the meat. Test the liquid as follows:
(a) Heat a little till it boils. Note any changes.
(b) Pour a little into a test-tube, add water till the colour nearly disappears, and apply the Biuret test for protein.
(c) Test a further quantity for reducing sugar using Fehling's Solution.
5. Prepare the ash and test it for iron, and phosphorus salts.
6. Determine the percentage of water in a given sample of meat.

Offal

The parts of animals other than the flesh or muscle that are eaten as food are collectively called 'offal'—an unsavoury title for some very valuable articles of food. Offal includes liver, kidney, sweetbreads, brains, heart, tripe, ox-tail, and tongue.

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Brains	75·0	9·1	8·3	0·0	1·1
Heart	65·7	15·7	17·4	0·0	1·2
Kidney	78·0	13·8	4·9	0·0	1·2
Liver (sheep)	70·0	17·0	6·0	5·4	1·6
Sweetbreads	65·0	12·7	19·1	0·0	1·6
Tongue	71·9	11·2	15·7	0·0	1·2
Tripe	87·0	9·8	0·8	0·0	0·5

Liver is a valuable food. Besides being a good source of first-class protein, it is the best food source of iron in a form that is readily made use of in the body. It also supplies copper and cobalt, and is a rich source of vitamins A and B factors, and contains a little vitamin D. Liver contains about five per cent glycogen or animal starch.

Kidneys are also valuable, particularly for iron and vitamin B factors.

Tripe is the stomach and intestine of the ox, cleaned and boiled. It is easily digestible, and besides supplying first-class protein it is a good source of calcium.

Sweetbreads is the name given to the thymus gland of the calf, though sometimes the pancreas is also sold under the same name. Sweetbreads are easily digested and absorbed.

Brains (sheep's), though quite easily digested, are not absorbed very well.

FISH

Fish resembles meat in composition but has less connective tissue and fewer extractives. There is generally a high percentage of waste in the form of skin and bones, even as purchased in the fish-shop, and this makes fish a fairly expensive food. Scaly fish are usually divided into fatty and non-fatty kinds according to the amount of fat present in the flesh, but there are a large number in the intermediate group, and such a classification is not very satisfactory. The flesh of non-fatty fish is usually white in colour, and that of fatty darker because the fat is spread through the flesh. The following classification of New Zealand fish is given by Dr Muriel Bell:

Fatty fish: tarakihi, groper, flounder, northern mullet.

Medium fatty fish: sole, gurnard, hake, southern kingfish, warehou, barracouta, moki, southern mullet or herring, John Dory, butterfish, trumpeter, trevally, northern kingfish or yellowtail, kahawai, maomao.

Non-fatty fish: snapper, blue cod, ling, red cod, elephant fish, whiting, dog-fish.

The range of food value is shown by comparing the two averages given below:

	WATER	PROTEIN	FAT	MINERAL MATTER
Fatty fish	68·9	18·2	11·5	1·4
Non-fatty fish	77·6	18·3	2·8	1·3

In should again be noted that as the amount of fat increases, the amount of water decreases.

Non-fatty fish are about equal to lean meat in protein content and have a fairly low caloric value, but fatty fish are equal to moderately fat meat in energy value. Fish easily breaks up into flakes after cooking owing to a greater loss of gelatine-yielding material than in meat. It is low in extractives and lacks the flavour of meat. When used too often in the diet, it tends to become monotonous. It is a good source of first-class protein, and supplies nicotinic acid, phosphorus, and some iron; kelp-feeding kinds of fish contain iodine, and this is an important point in their favour in a country where simple goitre is endemic in most parts. Fatty fish supply vitamins A and D, and the fish-liver oils such as cod-liver oil and halibut oil are the richest sources of these vitamins. Fish is low in

calcium except when the bones are eaten, as with tinned sardines, herrings, and salmon. Fish is nevertheless a better source of calcium than meat.

Since fish is often eaten fried it may take up a considerable amount of fat when cooked in this way. The following figures (from McCance and Shipp) are for the average of fifteen varieties of 'white' fish:

	WATER	PROTEIN	FAT	CARBOHYDRATE
(1) Steamed	75·4	22·4	1·38	0·0
(2) Fried	61·5	19·3	11·9	6·4

EXPERIMENT *To test fish.*

1. Examine the appearance.
2. Examine under the microscope (as explained for meat).
3. Test for protein using the xanthoproteic test.
4. Determine the percentage of water in a given sample.
5. Prepare the ash and test for phosphorus.

SHELLFISH

The shellfish most commonly used in New Zealand for food are oysters, mussels, pipis, and toheroas. These are not true fish, but may conveniently be considered here. As mentioned earlier, shellfish contain all three of the nutritive constituents—protein, fat, and carbohydrate, the whole animal being eaten, usually, not just the muscle only. The carbohydrate present is in the form of glycogen or animal starch, which is also found in liver.

	WATER	PROTEIN	FAT	CARBOHYDRATE	MINERAL MATTER
Crabs, crayfish	73·0	20·0	4·0	1·3	1·7
Prawns, shrimps	78·0	15·1	3·5	1·2	2·4
Oysters, mussels	80·0	12·8	1·4	4·0	1·8

Shellfish are a valuable source of iodine, and iron and copper are also present in greater amounts than in scaly fish.

EGGS

Since an egg must contain all that is needed for the development of the chick till hatching, it follows that eggs must contain first-class protein, calcium, phosphorus and iron, fat and vitamins A, B factors

and D. In fact, if eggs contained carbohydrate and vitamin C they would be entitled to be called perfect foods. The shell of an egg consists almost entirely of calcium carbonate, and as incubation goes on it loses about nine per cent of its weight by absorption, calcium being drawn from the shell as the growing embryo requires it. The white and the yolk of the egg have very different compositions. The white of an egg is often regarded as the single substance 'egg albumin', but this is not strictly correct. Besides the albumin, it contains complex protein groups united with a carbohydrate group, riboflavin, and other substances. The yolk of the egg is the chief storehouse of nutriment for the growing chick and is more concentrated than the white. The chief protein present is called 'vitellin', a phosphoprotein. (Compare with caseinogen, the chief protein of milk.) Small amounts of other proteins are present as well. The combined proteins of the whole egg are of high biological value. The egg yolk is also a good source of fat which is highly emulsified and very easily digestible, and contains vitamins A, D, and B factors. The mineral elements present are chiefly phosphorus, potassium, calcium, and iron.

The percentage composition of the whole egg and of the white and yolk separately are as follows:

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Whole egg	73·7	14·8	10·5	—	1·0
White of egg	85·7	12·6	0·25	—	0·59
Yolk of egg	50·9	16·33	31·75	—	1·09
Dried egg	5·85	45·80	42·0	3·15	3·15

The above figures are for hen's eggs. Other eggs used for food have about the same average composition, though the individual eggs may be larger. Eggs are thus a very valuable food, though no longer a cheap one. Generally speaking they are not as rich as meat or fish in protein value, but they contain a greater variety of nutritive substances and are very readily digested. They are admirably adapted to supplement foods rich in carbohydrate but not so rich in protein and fat, e.g. cereals. A lightly-cooked egg is very easily digested and well absorbed, and even hard-boiled eggs are not hard to digest.

Dried eggs, which were largely used during the Second World War, are prepared by a spray process similar to that used for drying milk. They are a very valuable commodity though they cannot replace the fresh egg fully in baking. During the drying process, a small amount of cane sugar is incorporated, as this prevents a change in the protein and helps to give a better 'beat'.

EXPERIMENT *To test eggs.*

Separate the white from the yolk of an egg and test each as follows:

A. *White*

1. Note the appearance and test the reaction to moistened litmus papers. Feel it and note whether it pours easily. (White of egg is alkaline, sticky, and viscous, i.e. it does not pour readily.)
2. Test for protein (Biuret and Xanthoproteic tests).
3. Pour some white of egg into a test-tube and place a thermometer in it so that the bulb is in the egg white. Place the test-tube in a beaker of cold water and heat gently, stirring occasionally with the thermometer. Note the temperatures at which, (a) cloudiness indicates the beginning of coagulation, and (b) the egg white is lightly cooked. (These temperatures will vary a little. Coagulation usually begins about 48-50°C and is complete by 70°C.)

B. *Yolk*

1. Test for protein by the Xanthoproteic Test.
2. Test for fat by the greasy spot method.

C. *Shell*

Place the shell in dilute hydrochloric acid and note the effervescence due to the evolution of carbon dioxide. (Test this with lime water.) Set aside until no more will dissolve and then test the acid extract for phosphate and calcium. Any undissolved portion should be tested for protein by the Xanthoproteic test.

D. *Whole Egg*

1. Find the percentage of water.
2. Reduce to ash and test for the presence of calcium, phosphorus, and iron.

SUMMARY

Meat is a rich source of first-class protein; lean meat contains about 20 per cent protein. If fat is present the fuel value is increased. Contains phosphorus, iron, and vitamin B factors. Readily digested and well absorbed.

Liver. As well as containing first-class protein, is the best food source of iron, and supplies vitamins A, B factors, and D, copper and cobalt.

Fish contains about 18 per cent of first-class protein. Divided into fatty and non-fatty kinds, which approximate to lean and moderately fatty meat in food value. Supply phosphorus and iodine but not iron. Fish liver oils are the best sources of vitamins A and D.

Shellfish. Besides first-class protein, supply iodine, iron, and copper.

Eggs contain about 15 per cent first-class protein and 10 per cent palatable and easily-digested fat. Good source of vitamins A, D, and B factors, and of phosphorus, calcium, and iron.

EXERCISE

1. Give a brief account of the physical structure of 'meat'.
2. What is the nutritive value of meat?
3. Why is liver such a valuable food?
4. Give a classification of fish used for food, with three examples of each class.
5. Why are fish a valuable food?
6. In what way (nutritionally) are shellfish remarkable?
7. Discuss the nutritive value of eggs.

(c) Cereals

THE CEREALS are the seeds of certain grasses which have been brought under cultivation. At first man hunted for his food with spear, bow, and fishing line—a precarious way of living which cannot support a large population and which provides a diet consisting largely of protein and fat. The next stage was the nomadic, in which man domesticated some animals and depended on them for his supply of milk and meat. Such a diet also contained little carbohydrate. The third stage is that of a stable agriculture based on the cultivation of wind-pollinated grasses. For equal areas such an agriculture can support five times the population that a nomadic way of life can. It produces a diet which is mainly carbohydrate and contains much less protein and fat than either of the previously-mentioned types. Such agriculture began thousands of years ago along the fertile river valleys of Mesopotamia and Egypt, and has now spread to every tropical, sub-tropical and temperate land. In fact, strains of cereals have been developed which will grow within the Arctic Circle. Wheat is the main cereal grown in the drier sub-tropical and temperate lands, e.g. Russia, North America, Europe, Australia, India, and New Zealand. In more humid and hotter climates, e.g. China, Japan, Malaya, Java, it is rice. In colder parts, such as Scandinavia, northern Germany, and parts of Russia, wheat does not ripen so well, and its place is taken by rye. In Scotland and the colder parts of the wheat-growing lands, the cereal grown is oats. Maize, first grown in America, is now largely grown also in Mediterranean countries, Rumania, Egypt, and South Africa. Barley is not much used for human food, but is largely grown in temperate climates for fodder and for making malt.

It is doubtful if modern civilization could have developed without a cereal agriculture to make the population static. Cereals in one form or another are the 'staff of life' in most parts of the world,

and provide 50 per cent to 90 per cent of the total food, depending on what other kinds and amounts of food are available. Cereals contain at least 70 per cent starch and this makes them a cheap and valuable energy-giving food.

In addition, they contain about 10 per cent of protein but this is inadequate for the maintenance of good health in the adult, or growth in the young, unless it is supplemented by first-class protein such as that supplied by milk and similar foods. This has been checked by feeding seventy successive generations of rats on a diet consisting solely of one-sixth dried milk and five-sixths ground *whole* wheat. This has proved quite adequate in every way for normal growth, health, and reproduction. It is important to remember that cereal protein, unless supplemented by milk proteins (preferably), or other first-class protein, is not adequate to promote growth in the young or for maintenance in the adult.

Even in New Zealand, where there is plenty of variety in the foods available, where there is an abundance of meat and cheese, and usually of fish and eggs as well, it is found that one-third of the day's protein comes from cereals. In countries which have not such an abundance of animal foods, cereals may provide up to 90 per cent of the day's protein.

Whole cereals are good sources of the vitamin B complex, containing more than enough of these factors to complete their own metabolism in the body. Highly-milled or 'refined' cereals, on the other hand, may contain only a small fraction of the vitamins present in the original grains. They may thus lack sufficient vitamins to complete their own metabolism in the body.

WHEAT

Wheat is undoubtedly the aristocrat of cereals. It was first cultivated in Mesopotamia, but now the skilful breeding of new varieties has extended its cultivation from the tropics to the Arctic Circle. From time immemorial wheat has always been ground to a fine powder, with or without the removal of the coarser particles, and this practice has led to so much controversy that it will be as well for us to examine the parts of the grain and see what the effect of the removal of some or any of them will have on the food value of the product. A grain of wheat (*Fig. 170*) consists of the following parts:

(a) *The bran* or outer protective covering of the grain. It is composed largely of cellulose and forms about 13½ per cent of the whole grain. Mineral matter including iron, and nicotinic acid are also found in it.

(b) *The aleurone layer*, just inside the bran layers, is rich in protein as well as in iron and nicotinic acid.

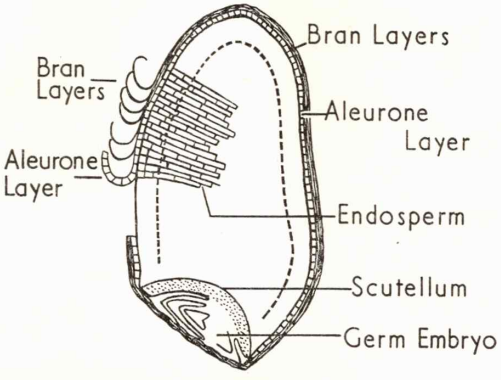


FIG. 170. Cross-section of a grain of wheat.

(c) *The endosperm* or storehouse of nutritive material for the growing plant when the seed germinates. It forms 85 per cent of the whole grain and consists of starch, proteins which form gluten, and a little thiamine.

(d) *The scutellum*, a thin layer between the endosperm and the germ or embryo, is able to change the materials of the endosperm into forms suitable for the growing embryo when the seed germinates. It is important in that it contains 60 per cent of the thiamine of the whole grain. Riboflavin, nicotinic acid, and iron are also found in it.

(e) *The germ or embryo* is the young plant and forms about 1½ per cent of the whole grain. It contains proteins, fat, sugar, nicotinic acid, riboflavin, and iron.

THE MILLING OF FLOUR

Prior to the Second World War, it was usual to make only the endosperm into flour, excluding the germ, scutellum, aleurone layer, and bran. In New Zealand, such flour contained 73 per cent of the whole grain, and was known as white flour. In 1946, to help the world food situation, the extraction rate in this country was raised to 80 per cent, i.e. 80 tons of flour were extracted from every 100 tons of wheat, instead of only 73 tons as previously; but in 1949 this was reduced to 78 per cent and that is the rate at present. This 'higher-extraction flour' requires additional machinery in the mills to separate the flour from the bran, but since the scutellum is included in the flour thus extracted, the thiamine content of the product is twice as great as it was in the 73 per cent flour. In fact, the higher extraction flour may be said to have the following advantages:

(1) It contains an increased proportion of the B vitamins of the whole grain.
(2) It contains most of the valuable proteins of the aleurone layer.
(3) Its nutritive value is as high as possible without too great an increase in indigestible cellulose.

Wholemeal flour contains about 92 per cent of the whole grain, the coarsest bran particles being excluded. It contains the germ as well as the other parts of the grain, so fat, as well as additional riboflavin and nicotinic acid, are present in it. The fat is inclined to go rancid fairly quickly and so wholemeal flour does not keep so well as flour in which the germ is not included.

The bread-making properties of wheat flour are due to the nature of the proteins in the endosperm. When flour is mixed with water to form dough, these proteins unite to form *gluten*, which is tenacious and can stretch considerably. A dough or other flour mixture containing gluten can be blown up into a spongy mass by forming carbon dioxide within it, using for this purpose either yeast or baking powder. Then, on baking, the gluten hardens and the dough 'sets' in its spongy condition, thus giving a risen or 'light' product which cannot be obtained from other cereal flours which do not contain gluten (see *Plate 14*).

The percentage composition of other cereal products commonly used for food in New Zealand is as follows:

CEREAL	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Barley, pearl	11·0	7·7	1·7	79·4	0·2
Bran, processed	8·0	10·9	4·2	72·3	4·6
Cornflour	12·0	0·7	0·3	86·6	0·4
Macaroni, spaghetti, vermicelli	10·0	10·7	2·0	76·8	0·5
Maize (meal)	12·5	9·2	1·9	75·4	1·0
Oatmeal, rolled oats	9·0	12·1	8·7	69·0	1·2
Rice, polished	11·0	4·9	0·5	82·8	0·7
Rye (wholemeal)	12·0	8·3	2·8	68·3	—
'Ryvita'	5·9	6·8	2·1	86·8	—
Wheat germ	12·0	25·8	10·2	48·1	3·9

Macaroni, spaghetti, and vermicelli are preparations of Italian origin made from a wheat flour paste prepared from a special variety of hard wheat with a high gluten content. They are made from the endosperm only and take up much water in cooking.

Semolina is another preparation made from the endosperm of the wheat grain. It is used chiefly for making puddings.

OATS

Of the cereals, oatmeal appears to be the most nutritious, being richer in fat and in protein than barley, rice, rye, or maize, while its carbohydrate content is also high.

Oatmeal is prepared by cleaning and grinding the grain. Rolling is now often used as a method of preparing oats, instead of grinding. The grains are subjected to great pressure between rollers, which ruptures the cell walls, breaks down the cellulose, and flattens the grains so that they are more easily softened by cooking. By the application of heat during the rolling process, the grains are at the same time partially cooked. Many of the *patent breakfast foods* on the market are treated more or less in this way. A considerable factor in their popularity is the shorter cooking time required, as compared with oatmeal porridge. The heat treatment may reduce the vitamin B_1 content of the products, and claims as to their nutritive value in this respect have not always been borne out by tests.

RYE

Next to wheat, rye is the great bread-making grain of the world. It is the only other cereal which can be used to make a raised loaf though the texture is much denser than in the wheaten loaf. Rye will grow in a colder climate and in poorer soil than wheat, which is largely grown in Northern Europe. It is little used in New Zealand.

RICE

Rice is the poorest of all cereals in protein, fat, and mineral matter. It may contain up to 76 per cent starch, and this is in the form of small easily-digested grains. When rice forms a high percentage of the total food (70 per cent or more), the diet is generally poor. In the milling process about three-quarters of the vitamin content of the grain is removed with the bran layers and germ, and where such 'polished rice' is the staple food, the deficiency disease beri-beri is widespread. In New Zealand rice should be regarded merely as a pleasant way of eating starch. What protein it has is of high biological value.

BARLEY

As previously mentioned, this is a cereal grown more for making malt for brewing, and for animal food, than for human consumption. As obtainable at the grocer's, it is in the form of 'pearl barley', and is used for soups, barley water, and sometimes for milk puddings.

Pearl barley consists of barley grains stripped of the bran layers and polished. It has a high starch and low protein content. A little thiamine is present. Barley water is practically 99 per cent water, but is a valuable demulcent (soothing) drink often used in cases of sickness.

MAIZE

Maize (sweet corn) is not much used for human food in New Zealand. It has roughly the same percentage composition as wheat and is as digestible as wheat. It is largely used for food throughout the United States of America, Mexico, South Africa, and parts of Europe; but it has very little of the vitamin B factor, nicotinic acid, which other cereals contain. Thus, in countries where maize is the staple food and the diet is generally poor (as in some of the poor districts in the United States of America), the deficiency disease, pellagra, is widespread.

Cornflour and Maizena are prepared from maize by washing away the protein and fat by means of dilute alkaline solutions, so that little but starch is left. They are therefore agreeable forms of starch which are easily digestible and, provided they are taken along with protein and fat, as in eggs and milk, are well adapted as foods.

Cornflakes consist of cooked maize or wheat which has been treated with malt and honey. It is then dried, rolled, and baked.

Pop-corn is made from a special small-grained variety of maize. The grains are roasted till they burst and then used as the basis for sweets.

In conclusion, cereals are rich sources of carbohydrate chiefly in the form of starch. About one-tenth of the weight of cereals consists of protein which is adequate for growth and maintenance provided that the diet contains enough milk and cheese to supply about one-tenth of the total protein requirement per day. Whole grain or high-extraction products are valuable sources of the B group of vitamins.

EXPERIMENT *To test cereals.*

The cereal to be tested should be in a finely-divided state, e.g. flour or meal.

(For tests 1 and 2, heat some of the ground food in water and use the liquid for the tests.)

1. *Carbohydrates*
   (a) Starch. Iodine test.
   (b) Reducing sugars. Fehling's Solution test.

(c) Sucrose. If there is no result in (b), heat some of the solution with two or three drops of concentrated hydrochloric acid. Cool and neutralize with caustic soda solution, and test again with Fehling's Solution.

2. *Protein*
   (a) Soluble protein. Biuret test.
   (b) Insoluble protein (test the solid food). Xanthoproteic test.
3. *Fat*. Greasy spot test.
4. *Mineral matter*. Prepare the ash and test for calcium, phosphorus, and iron.
5. *Water*. Find the percentage of water in the given food.

(d) Nuts and Legumes

NUTS

NUTS ARE a concentrated food, but do not play a very large part in the diet, except of vegetarians. This may be due partly to the large amount of waste in nuts as purchased in the shell, and partly to their reputed indigestibility. No other vegetable food is richer in fat than nuts. They contain a good deal of cellulose and are rich in protein, though this is not all complete or of very high biological value. They also contain a fair amount of carbohydrate. Nuts supply some calcium, iron, copper, and vitamin B factors. If they are finely chopped or ground, their digestibility is increased. The percentage composition of the commoner nuts is given below:

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Almonds	5·0	20·5	53·5	18·2	2·8
Brazil	8·0	13·8	61·5	13·3	3·4
Chestnut	52·0	2·3	2·7	32·9	—
Coconut	42·0	3·8	36·0	17·2	1·0
Hazel	6·0	12·9	64·0	14·4	2·7
Peanut	4·0	28·1	49·0	16·2	2·7
Peanut butter	1·2	29·4	47·1	20·1	2·2
Walnut	23·0	12·5	51·5	11·0	2·0

Though peanuts are given in this table, it should be noted that they grow in the ground and belong to the legume family. They are also called 'ground nuts' or 'monkey nuts' and are an important source of edible oil. Peanuts are one of the important food crops of the world. The protein of peanuts is used to make a synthetic fabric called 'ardil'.

Of the nuts, chestnuts are probably the kind most used for food, e.g. they form a large part of the diet of the poorer people in France, though they are not eaten as food in New Zealand. It is interesting to note that experiments have shown that a diet of selected fruits and nuts *can* supply all the body's needs for protein and energy for long periods. The fact that most nuts are rich in fat is made use of in the preparation of nut 'butters', e.g. peanut butter. These are concentrated foods, supplying fat, protein, vitamin B factors, and mineral salts.

EXPERIMENT *To test nuts.*

Use the finely-chopped nut for the following tests:

1. Test for the presence of
   (a) Carbohydrate (i) Starch;
   (ii) Reducing sugar.
   (b) Protein.
   (c) Fat.
2. Find the percentage of water.
3. Prepare the ash and test it for the presence of calcium, phosphorus, and iron.

LEGUMES

The seeds of leguminous plants, the dried peas, beans and lentils, are called legumes or pulses. These foods do not play a very important part in the diet of New Zealanders, except of vegetarians. They are good sources of carbohydrate, mostly in the form of starch, and contain quite high amounts of protein though it is of low biological value (lower than that of the cereals). When cooked (as cooked they must be to be digestible) they take up at least twice their volume of water.

Legumes are rich in vitamin B factors, and supply calcium, phosphorus, and iron. With the exception of soya beans, the legumes lack fat and therefore go well with fatty foods, e.g. pork and beans. They contain a bitter substance which many people find unpalatable. They are not readily digestible, but their nutritive value is quite high, and they could be used to a greater extent to advantage in lower-cost dietaries. Their average percentage composition is given below:

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Haricot beans	8·0	21·4	0·0	68·0	2·6
Lentils	6·0	23·8	0·0	68·0	2·2
Split peas	7·0	23·3	0·0	66·9	2·8
Soya beans	9·0	36·0	15·5	35·0	4·5

The soya bean, though used in China as early as 3000 B.C., has been used in this country only during and since the Second World War. It is remarkable for its high content of protein and fat and for the fact that its carbohydrate is not in the form of starch but of dextrins and sugar. It is not readily digestible unless ground. Soya beans are used by the Chinese and Japanese to supplement the deficiencies of rice, and various cheeses, pastes, and sauces rich in protein and fat are made from them. In the Far East, where cow's milk is not available, the beans have been used for centuries in the diet of infants, and they have supplied the greatest part of the protein in Chinese diets for 4000 years. The soya bean flour used in New Zealand is obtained from beans which have been heat-treated and have had their oil largely removed. This flour is sometimes mixed with ordinary flour in making bread, buns, scones, etc. especially to increase the protein intake in vegetarian diets.

EXPERIMENT *To test legumes.*

As before, use the legume finely ground, for the following tests:

1. Test for the presence of
   (a) Carbohydrate (i) starch,
   (ii) reducing sugar.
   (b) Protein.
   (c) Fat.
2. Find the percentage of water.
3. Prepare the ash and test it for calcium, phosphorus, and iron.

SUMMARY

Cereals. Very rich in starch and fair in protein which is of higher biological value than that of nuts or legumes. Whole cereals supply the B group of vitamins. Should be supplemented by milk, eggs, cheese. Refining removes bran and germ and with them most of the vitamins, minerals, and valuable proteins. Heat treatment of prepared breakfast cereals may very much reduce the thiamine content.

Nuts. Concentrated foods. Richest of vegetable foods in fat (except chestnuts), and many contain as much protein as meat, though it is not all complete nor of high biological value. Starch is also present, especially in chestnuts. Nuts supply iron, copper, a little calcium, and some vitamin B factors.

Legumes. Rich in starch and contain as much protein as meat, but it is of low biological value. Vitamin B factors, calcium, phosphorus, and iron are also present. Except for soya beans, no fat is present. Should be used with fats.

EXERCISE

1. List four cereals which are largely grown in different parts of the world to provide 'human food', giving the main areas in each case.
2. What do cereals contribute towards the daily diet?
3. What is a 'refined' cereal, and how does it differ from an unrefined or whole grain one?
4. Do you think that bread is entitled to be called the 'staff of life'? Give reasons for your answer.
5. What is the relationship between vitamin B complex and the utilization of carbohydrate in the body?
6. Draw a grain of wheat showing the chief parts, and say which food constituents are chiefly found in each part.
7. What is meant by 'higher extraction flour', and what are its advantages over a flour of lower extraction?
8. Why is wheat flour but not oatmeal or barleymeal able to be used for breadmaking?
9. What is the value in the diet of foods such as macaroni, spaghetti, semolina, and cornflour?
10. In the preparation of prepared cereal foods, what important constituent of the whole grain may be very much reduced by the heat treatment such products undergo?
11. What food constituents are richly present in nuts?
12. What is the food value of the pulses?
13. Write a paragraph on the soya bean as a food.

(e) Vegetables and Fruits

VEGETABLES

THERE IS no hard and fast classification of vegetables, since the parts of plants used as food are of great variety—shoots, leaves, stems, roots, tubers, and other storage parts all being used, as well as fruits and seeds. The following classification should be used as a rough guide only:

1. Green and leafy vegetables, e.g. cabbage.
2. Leguminous green vegetables, e.g. green peas.
3. Salad vegetables, e.g. lettuce.
4. Bulbs, roots and tubers, e.g. onions, carrots, potatoes.
5. Seeds, e.g. cereals. This group has already been dealt with in the previous section.
6. Fruits, e.g. tomatoes.

Green and Leafy Vegetables

These are chiefly members of 'the cabbage family' and include spring, winter and savoy cabbages, broccoli, cauliflower, Brussels sprouts and kale. Spinach and silver beet are other popular leafy vegetables.

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Broccoli	79·0	4·7	0·4	13·4	2·5
Brussels sprouts	85·0	4·4	0·0	9·2	1·4
Cabbage	92·0	1·5	0·0	5·3	1·2
Cauliflower	92·0	2·4	0·0	4·6	1·0
Kale	87·0	3·9	0·0	7·4	1·7
Silver beet	88·0	2·6	0·0	7·6	1·8
Spinach	91·0	2·7	0·0	5·0	1·3

As the table shows, green vegetables are 85 per cent to 92 per cent water and are deficient in fat. They contain a little carbohydrate, mostly starch, and a small amount of protein, which is of good biological value. Their importance lies in their content of mineral matter and vitamins. All green plants contain carotene, which, as you have learned, is the precursor of vitamin A. Vitamin C is also present in good amounts, green vegetables being high on the list of sources of this vitamin. Vitamin B factors are also present in most green vegetables. As far as mineral matter is concerned, the green vegetables are one of the most important sources of iron, and some calcium is present, particularly in kale. Though spinach also contains a fair amount of calcium, this is usually not available to the body. All vegetables supply crisp cellulose and add colour and variety to meals.

EXPERIMENT *To test a green vegetable.*

1. Before testing for starch the vegetable should first have the chlorophyll removed. Boil it for a few minutes in water to soften it and then soak it in warm alcohol (methylated spirits).

WARNING: Remember that alcohol is very inflammable. Heat it by placing a test-tube containing it in a beaker of hot water. When the chlorophyll has dissolved out, test the leafy vegetable for starch in the ordinary way.

2. Test for the presence of protein (Xanthoproteic test).

3. Find the percentage of water.

4. Reduce to ash and test for iron and calcium.

Leguminous Green Vegetables

These are green peas, French, broad and runner beans, and like the previous group, are valuable for carotene and vitamin C. When they are shelled and only the seeds eaten, as in the case of green peas and usually of broad beans, their protein and carbohydrate values are increased; otherwise they differ little from other green vegetables in food value (see *Plate 15*).

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Beans broad	77·0	7·2	0·5	14·3	1·0
Beans, French and runner	92·0	1·1	0·0	6·5	0·4
Peas, green	79·0	5·8	0·0	14·4	0·8

Salad Vegetables

Lettuce is the chief salad vegetable used in New Zealand, but others sometimes used are celery and endive. Shredded raw cabbage can be used as a salad vegetable in winter. Though radishes are not leaves, they are given here because they are used in raw salads. They supply some vitamin C. Lettuce and endive are valuable for carotene and the greener the leaves the richer their 'vitamin A value'. The green outer leaves also contain more vitamin C than the white heart leaves. Salad vegetables add flavour and variety to meals. Celery, which is blanched for table use, supplies some calcium and iron. Parsley has a higher food value than other salad vegetables, but it is used mostly as a garnish and in small amounts for flavouring. It is a rich source of vitamin C, carotene, and iron.

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Celery	94·0	0·9	0·0	4·7	0·4
Lettuce	95·0	1·1	0·0	3·1	0·8
Parsley	79·0	5·2	0·0	13·6	2·2
Radishes	93·0	1·0	0·0	5·0	1·0

Bulbs, Roots, and Tubers

These are parts of plants where food is stored as sugars and starches. They are usually underground parts, but the onion and leek are modified leaves. New potatoes and swede turnips are quite valuable for their vitamin C content, and so are leeks and spring onions. Carrots supply carotene, and vitamin B factors are present

in most of these vegetables in small amounts. More carbohydrate is present, on the average, than in the green leafy vegetables. Because they form a regular part of the daily diet and are eaten in fair amounts by almost everyone, potatoes require special mention as sources of vitamin C and iron. New potatoes (up till May) may contain four times as much vitamin C as old potatoes (in September or later). After the establishment of the potato as a food crop in Europe (Sir Walter Raleigh is said to have introduced it into England in 1586), scurvy, which used to be very prevalent during the long winters, disappeared. Since then outbreaks of scurvy have occurred in Ireland and Norway when the potato crop has failed because of disease.

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Beetroot	87·0	1·8	0·0	10·8	0·4
Carrots	90·0	0·7	0·0	8·3	1·0
Leeks	88·0	2·5	0·0	8·5	1·0
Onions	93·0	0·9	0·0	5·6	0·5
Parsnips	83·0	1·7	0·0	14·7	0·6
Potatoes	78·0	2·0	0·0	19·6	0·4
Sweet potatoes	65·4	1·9	0·1	31·9	0·7
Turnips	93·0	0·8	0·0	5·4	0·8
Yams	76·1	2·3	0·1	20·7	0·8

EXPERIMENT *To test root vegetables.*

The grated vegetable shaken up with water may be tested directly for the presence of starch, sugar, and protein in the usual way. The percentage of water should be found and the ash prepared and tested as for green vegetables.

Fruits Used as Vegetables, and Unclassified Vegetables

This group includes tomatoes, pumpkins, marrows, and cucumbers, which are edible fruits, and asparagus, rhubarb and mushrooms.

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Asparagus	94·0	2·0	0·0	3·4	0·6
Cucumber	96·0	0·6	0·0	2·4	1·0
Marrow	98·0	0·5	0·0	0·3	1·2
Mushrooms	92·0	1·8	0·0	5·6	0·6
Pumpkin	88·0	1·5	0·0	9·9	0·6
Rhubarb	94·0	0·6	0·0	4·6	0·8
Tomatoes	93·0	0·9	0·0	5·3	0·8

Like the green and salad vegetables, these foods contain a high proportion of water. Their chief value as foods is to supply us with mineral matter and vitamins, and to give flavour and variety. Asparagus supplies some vitamin C, and tomatoes are rich sources of carotene, vitamin C, and iron. The vitamin C of tomatoes is retained to a large extent after canning.

General Conclusions

(1) All vegetables are valuable sources of mineral matter. Green vegetables are one of the best sources of iron.

(2) Vegetables are sources of vitamins C and B complex. Green and yellow vegetables also supply carotene.

(3) Vegetables provide pleasing flavours and add colour and variety to meals.

(4) Vegetables supply cellulose and a little carbohydrate, mostly starch. Root vegetables have more carbohydrate than the others. Vegetables lack fat; but most contain a little protein which is of good biological value.

FRUITS

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Apples	85·5	0·3	0·0	13·9	0·3
Apricots	87·0	0·6	0·0	11·8	0·6
Bananas	71·0	1·1	0·0	27·1	0·8
Currants, black	77·0	0·9	0·0	21·5	0·6
Grapes	75·0	0·6	0·0	23·8	0·6
Oranges	86·0	0·8	0·0	12·6	0·6
Peaches	86·0	0·6	0·0	12·6	0·8
Pears	83·0	0·2	0·0	16·4	0·4
Plums	81·0	0·6	0·0	18·0	0·4
Strawberries	89·0	0·6	0·0	10·2	0·2

The fruits, like the vegetables, are valuable chiefly as sources of vitamin C, and sometimes of carotene and iron. Fruit has distinct value as an appetizer—it needs only the sight of a delicious tree-ripened peach or apricot, a bunch of grapes, or a rosy apple, to 'make the mouth water'. This means that the digestive juices have already begun to flow, ready to digest the fruit as soon as it arrives in the mouth and stomach. Besides the elusive flavours which are so characteristic of fruits, they also contain mild fruit acids, sugars, and

cellulose. It is the latter which is responsible for the characteristic crispness of apples, the grainy particles in pears, the rather stringy texture of some plums, and the 'membrane' that divides an orange into segments. The arrangement of the cellulose makes it possible for a very large amount of water to be held in fruits, as the preceding table shows.

As you can see, the percentage of water present in fruit varies from about 70 per cent to 90 per cent. Those fruits which have 20 per cent or more of solids are considered to be 'food fruits', while those with less than 20 per cent are called 'flavour fruits'. On this basis, only bananas, black currants, and grapes would be classed as food fruits. Though starch may be found in unripe fruits, very little is ever present in fully ripe fruits. Unripe bananas, for example, are sometimes made into flour which contains 80 per cent starch. The main sugars present in fruits are glucose and fructose. Cellulose and pectin are also present in fruits, and during the ripening of the fruit some of the latter is changed into sugars called pentoses. These are not digestible in the body. The mineral matter present in fruits is mainly in the form of potassium salts of several organic acids such as citric, tartaric, and malic. These have an agreeable flavour, and when oxidized in the body they are converted into alkaline carbonates which help to maintain the correct reaction of the blood. It is for this reason that even acid-tasting fruits do not cause 'acidity' or 'acidosis' as some people erroneously believe. Even the sourest lemons are valuable in maintaining the *alkaline* balance in the body. A few fruits contain appreciable amounts of iron, e.g. loganberries, raspberries, red and black currants. Nearly all the fresh fruits contain vitamin C. Notable exceptions are grapes, plums, and some apples.

EXPERIMENT *To test fruit.*

1. As before, chop some of the fruit, add water, and test for sugars (first for reducing sugars and then for sucrose). If the fruit is unripe the presence of starch may also be shown.
2. Determine the percentage of water present.
3. Reduce some of the fruit to ash and test for the presence of potassium and iron.

Dried Fruits

These are prepared from the fresh fruits by evaporation of water, either by exposure to sun (sun drying) or by exposure to artificially heated air with controlled conditions of temperature, humidity and air-flow (dehydration). These methods will be mentioned again in the chapter on preservation of food. The chief effect is to remove most of the water and thus to increase the proportion of solids.

	WATER	PROTEIN	FAT	CARBO-HYDRATE	MINERAL MATTER
Apricots, dried	15·0	3·9	0·0	77·2	3·9
Currants	22·0	1·7	0·0	73·9	2·4
Dates	15·0	2·0	0·0	81·8	2·0
Figs	18·8	4·3	0·3	74·2	2·4
Prunes	28·0	2·3	0·5	67·6	1·6
Raisins	22·0	1·1	0·0	76·1	0·8
Sultanas	18·0	1·7	0·0	78·1	2·2

Dried fruits are therefore concentrated foods with a high proportion of carbohydrate, chiefly sugars. The date is the chief food of the Arab. (Compare its percentage of sugar with the percentage of starch in rice, which is the chief food of the Hindu.) Dried fruits are fairly rich sources of iron and copper. Figs are especially good sources of iron and also of calcium. Dried fruits contain no vitamin C, and so cannot fully replace fresh fruits in the diet.

EXPERIMENT *To test dried fruits.*

1. Chop some of the dried fruit to be tested, add water, and test for sugars, starch and protein. (Biuret test on the liquid.)

2. Determine the percentage of water.

3. Reduce to ash and test for the presence of iron, calcium, and potassium.

(f) Miscellaneous Foods

It now remains for us to consider a few other commonly used foods which have not so far been mentioned in this section of our work. These foods are known as 'supplementary energy foods' because, generally speaking, they contain no protective vitamins or mineral salts, but are sources of energy only, in the form of sugar, starch, or fat.

Cane Sugar

Cane sugar or sucrose is a complex sugar or disaccharide, which is 99·9 per cent pure. It is very largely used for sweetening food, but apart from its value as a fuel it has no other value in the diet. It is an outstanding example of a 'one-sided' food.

Honey

Honey is a mixture of sugars collected by the bees from the nectaries of flowers. It contains about 23 per cent water, 76·4 per cent carbohydrates (consisting of roughly 75 per cent invert sugar and a little sucrose and dextrin), 0·4 per cent protein, and 0·18 per cent mineral matter. It has no vitamins.

Arrowroot, Sago, and Tapioca

These are preparations containing over 90 per cent carbohydrate, mostly starch. *Arrowroot* is obtained from the rhizomes of a plant, the maranta, which grows in the West Indies. The rhizomes are mashed up with water and the starch which separates out is strained off, allowed to settle, and then dried. It is an easily-digested and well-absorbed carbohydrate food. *Sago* is obtained from the pith of the sago palm, and *Tapioca* from the tubers of the cassava, a tropical plant of South America. Heat treatment after drying causes the formation of the little pellets characteristic of these two products. It should always be remembered that these foods are simply agreeable forms of starch, and they should therefore be eaten with foods rich in protein, fat, and vitamins, e.g. milk and eggs.

Margarine

Margarine is a butter-substitute largely used in Great Britain, United States of America, and other countries which have not the abundance of butter to which New Zealanders are accustomed. In Great Britain, margarine imitates butter as far as possible in its colour, the melting point of its fats, the nature of its fats, and so on. Margarine (in Great Britain) is manufactured by emulsifying warm animal or vegetable fats with soured skim milk or pasteurized milk, and rapidly freezing the mixture in thin films, in which state it is left to mature for a day and then beaten into blocks. Vitamins A and D are added to the oils used, before mixing, so that nutritionally such margarines are equal to butter, though they do not contain the same glycerides. Like butter, margarine may contain not more than 16 per cent water and has salt added to it. The raw materials used are copra (dried coconut), cotton seed, palm kernels, peanuts, and hydrogenated whale oil. A margarine made entirely from animal fats is sometimes called 'oleomargarine'. In some kinds, both animal and vegetable fats are present, but the method of manufacture is as outlined above for all kinds. Definite regulations control the labelling of boxes of margarine, and if it is wrapped for retail sale, regulations as to the marking of the wrappers have again to be complied with.

In New Zealand margarine has no vitamins added to it so it is not comparable to the 'vitaminized' margarine of Great Britain. It is prepared mostly from beef-fat and is used for cooking only.

Other Cooking Fats

Lard and Dripping are practically 100 per cent fat and their vitamin value is *nil.* Lard is a soft fat obtained from pork, and is used largely for pastry-making. Dripping is melted fat obtained from any meat on cooking.

Suet, obtained from the butcher, is the fat of the ox and still contains some membrane. Commercially-prepared suet, as bought in the packet, is such fat, rendered, flaked, and mixed with some form of starch to stop the flakes from sticking together. These forms of suet contain from 71 per cent to 94 per cent fat.

Vegetable Fat, as sold in New Zealand for cooking purposes and for making confectionery, is mostly prepared from hydrogenated coconut oil.

SUMMARY

Green and leafy vegetables contain cellulose, a little starch, and a very small amount of protein. Valuable sources of iron and other minerals, especially potassium and magnesium. Good sources of carotene, and vitamin C and vitamin B factors are also present. Give flavour, colour, and variety to meals.

Leguminous green vegetables. When shelled and only the seeds eaten, protein and carbohydrate are supplied in addition to the factors already given under green and leafy vegetables.

Salad vegetables. Green leaves contain mineral matter, cellulose, vitamin C, and carotene. Valuable for flavour and variety.

Bulbs, roots, and tubers. Storage parts of plants. Richer than other vegetables (except cereals and pulses) in carbohydrate. Valuable sources of mineral matter and of water soluble vitamins. Potatoes and swede turnips valuable for vitamin C.

Tomatoes. Valuable for vitamin C and carotene.

Fruits. Contain some sugar. Valuable for vitamin C and mineral matter. Give colour, flavour, and variety. Those with more than 20 per cent solids are classed as food fruits.

Dried fruits. Water is largely removed from fresh fruits by sun-drying or dehydration. Contain high proportion carbohydrate, chiefly sugars, and mineral matter. No vitamin C is present.

Supplementary energy foods supply chiefly carbohydrate or fat and little else of value. Margarine may have vitamins A and D added (not in New Zealand), and is then a butter-substitute.

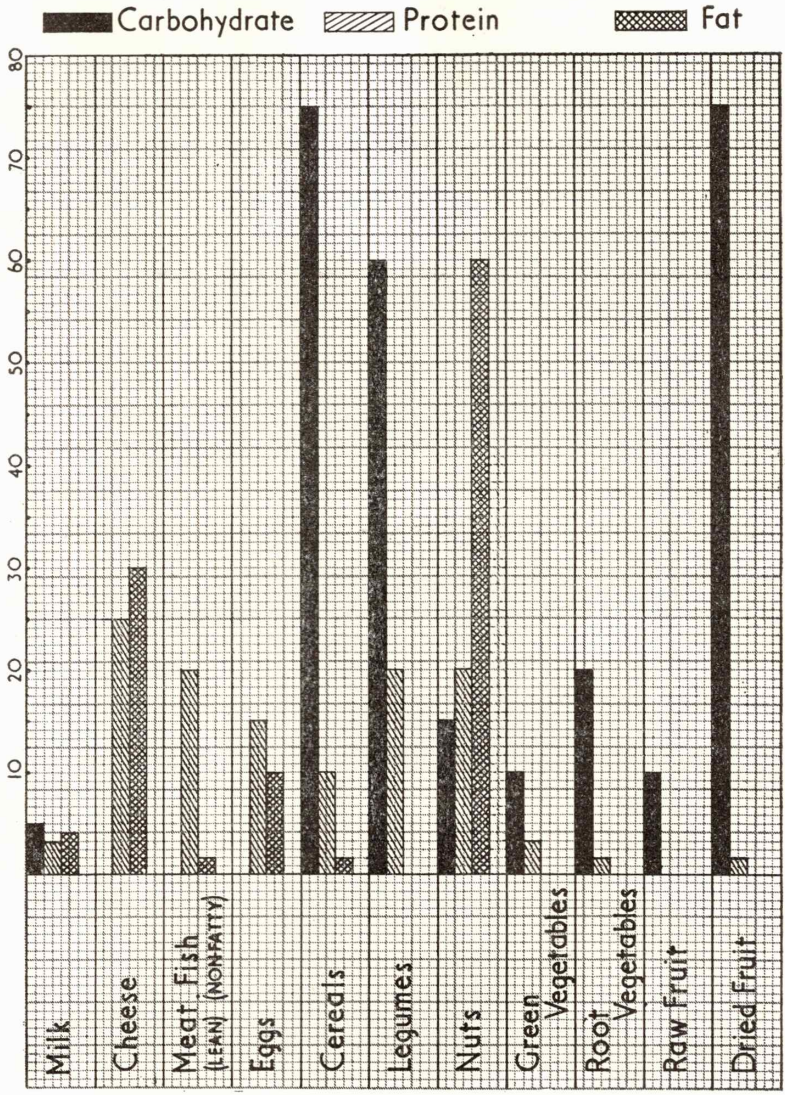


FIG. 171. The main food groups as sources of carbohydrate, protein and fat. ((Approximate percentages.)

	Vit. A or carotene	Vit. B complex	Vit. C	Vit. D
Milk	+	+	+	+
Cheese	+	+		+
Meat, Fish		+		
Eggs	+	+		+
Cereals (whole)		+		
Legumes		+		
Nuts		+		
Green Vegetables	+	+	+	
Root Vegetables	+	+	+	
Raw Fruit	+	+	+	
Dried Fruit				

+ = Good source
+ = Fair source

FIG. 172. The main food groups compared as sources of vitamins.

EXERCISE

1. Give a classification of vegetables used as food, with three examples of each.
2. Name three important food constituents provided by green leafy vegetables.
3. What food constituent, in addition to those given in answer to No. 2, do leguminous green vegetables provide?
4. What are the chief uses of 'salad vegetables' in the diet?
5. Write a paragraph on the value of potatoes in the diet.
6. What is the chief value of fresh fruits in the diet?
7. How do dried fruits differ in composition from fresh fruits? Can they replace fresh fruits fully, in the winter diet?
8. Write an account of the value of refined cane sugar in the diet.
9. What is the food value of honey?
10. Write a brief account of the manufacture and use in the diet of margarine.

24

The Preparation, Cooking and Serving of Foods

WE HAVE LEARNED the values of the different foods as sources of the essential food constituents; but many of these foods in their natural state are unfit for human consumption, e.g. the cereals and pulses, and therefore require treatment before eating. Cooking is a process that has been used since time immemorial, and in this chapter we shall describe briefly the main methods and their effects on the different foods and food constituents. Knowledge of the composition of foods in their natural condition is valuable, but you should also know what effects the different methods of cooking have upon them. Cooking may alter the value of a food quite considerably.

With foods that are eaten raw, e.g. most fruits and salad vegetables, the chief consideration is that they be fresh, and in the case of fruits, properly ripe. Under-ripe fruit is not fully matured; over-ripe fruit has begun to decay. Fruit eaten raw may require to be washed to remove dust, micro-organisms, or sprays. Salad vegetables should, whenever possible, be picked fresh from the garden just before use, washed thoroughly, and prepared for the table at once. Otherwise they should be purchased as fresh as possible. Such fresh fruits and salad vegetables are valuable chiefly for their vitamin C and mineral salts. As vitamin C is the least stable of all the vitamins, special care must be taken to conserve it in foods as much as possible (p. 310).

REASONS FOR COOKING FOODS

Foods are cooked because:

1. The idea of eating certain foods raw is distasteful to us, e.g. raw eggs or raw meat do not appeal to us as foods.
2. To develop flavour and so increase palatability.
3. To soften the connective tissues of meat and to burst the starch grains of vegetables, thus making them more digestible.
4. To sterilize foods by destroying parasites or bacteria which might be in or on them.

However, unless cooking is done carefully, with an eye on the composition of the food and the effect of heat on its constituents a food may be made more difficult to digest, or have its food value lessened by wrong or careless methods of cookery. For example, eggs may be over-coagulated, fried foods may become soaked in fat, and vegetables may be over-cooked.

EFFECT OF HEAT ON THE FOOD CONSTITUENTS

Sugars. Sugars are little affected by cooking. They dissolve in the liquid and sweeten the food and there may be some slight conversion to caramel, which adds to the flavour. In the case of acid fruits there is some conversion of cane sugar into invert sugar.

Starch. The cooking of starch is essential for digestion in the human body. Under the influence of moist heat the cellulose cell walls are softened, the starch grains swell up and burst so that the starch is set free or 'gelatinized', and therefore can be acted on by the digestive juices. Under the influence of dry heat, as in the oven, some starch is converted into dextrin, e.g. in the crust of bread.

Cellulose. Cellulose is little affected by cooking for a short time, but if vegetables are cooked for too long a time the cellulose loses its crispness and becomes soft and slimy.

Proteins. Proteins are coagulated by heat and this frequently improves their palatability and digestibility. Low temperatures give a tender product but high temperatures cause the protein to shrink and become tough, hard, and indigestible.

Fats. Fats are little affected by cooking. They melt on heating, and sometimes become granular on cooling, e.g. dripping. Very high temperatures cause decomposition with the formation of irritating substances, e.g. acrolein.

Mineral Salts. These, being mostly soluble in water, may dissolve out into the cooking liquid.

Vitamins. Vitamins A and D are insoluble in water and unaffected by ordinary cooking methods. Vitamin B factors and vitamin C are soluble in water and so may dissolve into the cooking water. Vitamins B_1 and C are destroyed by long cooking or by an alkali such as baking soda.

METHODS OF COOKING

The chief methods used for cooking foods may be briefly described as follows:

Baking. The food is cooked in a heated oven, the sides of which radiate heat to the food. When applied to meat, this method is usually termed *roasting.*

Grilling. The food is cooked by being placed under a gas or electric griller. When this is heated red-hot it radiates heat to the food.

Boiling. The food is cooked in briskly boiling water, or, in the case of meat, allowed to simmer gently till cooked. *Simmering* is cooking in water below boiling point, the temperature being about 180°F.

Stewing. The food is cut into small pieces and allowed to simmer till cooked.

Steaming. The food is cooked either in the upper part of a double boiler or in a steamer. In the latter case, it is surrounded by steam from the boiling water in the lower part of the steamer.

Frying. The food is cooked in hot fat at a high temperature. Three methods are used (1) Cooking in just sufficient fat to stop the food from burning. This method is called sautéing. (2) Cooking in a small quantity of fat. This is pan or shallow fat frying. (3) Cooking in sufficient fat to cover the food completely. This is deep-fat frying.

The Cooking of Meat

In roasting meat, the oven should be kept at a temperature of 300°-350°F. for the whole time of cooking. In this way there is less shrinkage of the joint than if the initial temperature is very high. The temperature of the oven is great enough to coagulate the outside of the meat and to cause the inside of the meat to 'cook in its own juices'. Although the temperature inside a joint of meat is always below boiling point, it is still high enough to coagulate the protein.

Grilling is a quick method suitable for chops and tender cuts of steak. The meat is placed under a red-hot griller till one side is cooked, turned, and then cooked on the other side. The heat, applied first on one side and then on the other, is sufficient to cook the meat through. As there is no time for the connective tissues to be softened, this method can be used only for the best cuts of meat.

In boiling meat, the piece is put into boiling water sufficient to cover it and then simmered gently till cooked. Corned beef is put into cold water to help extract some of the salt.

In stewing, the meat is usually browned in hot fat and then cut into small pieces and covered with water in which it is allowed to cook gently for a long time. In this way the proteins are coagulated without being hardened, and the connective tissues are changed to gelatin during the long, slow cooking process. Stewing may be used with success in cooking the tougher cuts of meat. As the liquid is served as part of the dish, the loss of soluble materials from the meat into it does not matter.

EXPERIMENT *To study the cooking of meat.*

1. Place a piece of meat in water and leave it to soak for an hour. Now pour some of the liquid into a test-tube, place a thermometer in it and heat gently in a water-bath, noting the temperature at which coagulation takes place (shown by a change in colour).

2. (a) Boil some gristle in water for several hours.
(b) Test the liquid for protein.

3. Put a small piece of raw meat into boiling water and cook it for three or four minutes. Then take it out, cut it across, and note the change in appearance of the outer surfaces.

4. Sear a small piece of raw meat on both sides, on a hot plate or small pan. Cut across and examine.

5. If the co-operation of a cookery class is available, the percentage loss during cooking should be calculated in the following cases:

(a) A small roast of beef, weighed before and after cooking. (It must be allowed to cool before the second weighing.)

(b) A small joint of mutton, boiled in the usual way. (Again, the second weighing must be done after the meat has cooled.)

(c) The water from the boiled mutton should be tested for protein (Biuret test).

These experiments should show that soluble protein dissolves out when meat is soaked or cooked in water. This protein coagulates at a temperature below the boiling point of water (from about 50-70°C). A higher temperature hardens the outside of the meat. Long slow cooking converts gristle (collagen) into gelatin, which sets into a jelly on cooling.

The Cooking of Fish

The proteins of fish are affected by heat in the same way as the proteins of meat. Fish has less connective tissue and so cooks more quickly than meat. It must not be over-cooked or it will fall to pieces, due to the conversion of its connective tissues into gelatin. Boiling, steaming, and frying are the most commonly used methods of cooking fish. The aims are to coagulate the proteins, and to do this without too great loss of soluble mineral salts and extractives. If fish is 'boiled', it should cook gently at simmering temperature only.

The Cooking of Eggs and Cheese

As in the case of the other protein foods so far considered, the aim in cooking eggs is to coagulate the protein so that the food may be palatable but not indigestible. Raw eggs are not as easily digested as cooked eggs. You know that the proteins of the egg

will coagulate well below the boiling point of water. It is therefore not necessary to have the water boiling all the time, to cook an egg. It will, of course, take longer to cook at the lower temperature, but the egg will coagulate without hardening. Whatever method is used to cook eggs, whether it be boiling, poaching, or scrambling, or in custards and other dishes containing eggs and milk, a low temperature will give the best results. The latter dishes should not be cooked directly over a flame or in a hot oven but in a double-boiler or in a dish of water in the oven. When scrambled eggs and custards 'go watery' it is because they have been cooked at too high a temperature and the proteins have shrunk and become tough.

Cheese, besides being rich in protein, is also rich in fat. If it is heated at too high a temperature, the proteins shrink and become tough and the fat melts and separates from the rest of the food. Therefore cheese dishes, also, should be cooked slowly at a low temperature. The proteins of cheese (i.e. of milk) are of course quite palatable and digestible uncooked; but cheese is often added to give flavour to cooked dishes.

EXPERIMENT *To study the cooking of eggs and cheese.*

1. Revise part A 3 of experimental work on eggs, p. 283.
2. (a) Heat a small piece of cheese on a metal plate or small pan directly over a flame.

   (b) Heat a small piece of cheese in milk, slowly over a very low flame, or in another dish of boiling water.

Compare the two products and draw conclusions as to the better method of cooking cheese.

All protein foods should be cooked slowly at a low temperature to avoid over-coagulation of the protein. They lose water on cooking and become more concentrated.

The Cooking of Legumes (Dried)

Dried peas and beans require soaking before cooking in order to replace the water given up in drying. Because of the nature of the protein in legumes, care must be taken or a hard product, which no amount of cooking will soften, will result. This protein will unite with calcium compounds which are present in hard water to form insoluble substances. Hence, if the water is hard, baking soda should be added to the soaking water. Now this is contrary to what you have learned previously, viz. that baking soda must not be added to foods in cooking because it destroys vitamins B_1 and C. This is the only exception to that rule for the reason stated above. Dried legumes do not contain vitamin C and in most diets are not relied

on for their vitamin B_1, so in this case the loss is not regarded as vitally important, as it would be in the case of green vegetables. The water to which the soda is added must be discarded either before cooking or after par-boiling, in order to preserve the colour and flavour, and to prevent the breaking up of the legumes before they are fully cooked.

Dried peas and beans should be soaked in hot water for several hours before cooking. Split peas and lentils do not require soaking. These foods should be cooked slowly for a long time.

EXPERIMENT *To study the cooking of legumes.*

1. Soak some split peas or lentils in water overnight.

2. Strain off the liquid and test it for the presence of protein, starch, and mineral matter.

3. Cook some of the peas or lentils in water to which baking soda has been added to make it slightly alkaline.

4. Strain off the liquid and test as in 2. Compare the results and draw conclusions.

5. Cook the remainder of the soaked peas or lentils in water made hard by adding calcium sulphate. Compare the time required with that in 3, and draw conclusions.

THE COOKING OF CEREALS (and other starchy foods)

According to the treatment before marketing, cereal products may be quick-cooking or long-cooking. Compare, for example, a 'prepared' breakfast food and coarse oatmeal, for making the morning porridge. The coarser the cereal the more fibrous material, and so the longer the time required. Long slow cooking is desirable to soften the cellulose and burst the starch grains, and also to develop flavour. Except for rice and pearl barley, which can be cooked directly in boiling water, cooking in a double-boiler or other method of long slow cooking is advocated for all types of cereal foods.

EXPERIMENT *To study the cooking of rice.*

1. Weigh out a teaspoonful of rice or pearl barley.

2. Drop it into boiling water in a large beaker and cook till the grains are soft (about 20 minutes).

3. Strain and let surface moisture drain off.

4. When cool, weigh again.

5. Calculate the amount of water absorbed by the grain in cooking. Express it as a percentage.

The Cooking of Green Vegetables

We have seen that the green vegetables contain a large percentage of water and a small percentage of carbohydrate, protein, and mineral matter. Vitamin C, vitamin B complex, and carotene are also present. It is the vitamins and mineral salts which are the valuable constituents of green vegetables, and in cooking one of the aims must be to conserve them as far as possible. At the same time, the starch must be cooked, the cellulose softened, and the green colour and flavour of the vegetable retained.

Vitamin C Loss in Foods

Vitamin C is destroyed by an enzyme present in plant cells and set free when these are damaged by bruising, shredding, grating, cutting up, or by heat. It is readily oxidized, soluble in water, and destroyed by alkali or if copper cooking utensils are used. Its loss is slower if acid is present, e.g. in tomatoes. The loss by enzyme action is the greatest cause of loss, and takes place rapidly in green vegetables, e.g. if lettuce is shredded for some time before being used in a salad; and more slowly but nevertheless steadily in other vegetables which are peeled, cut up, and left for some time before cooking.

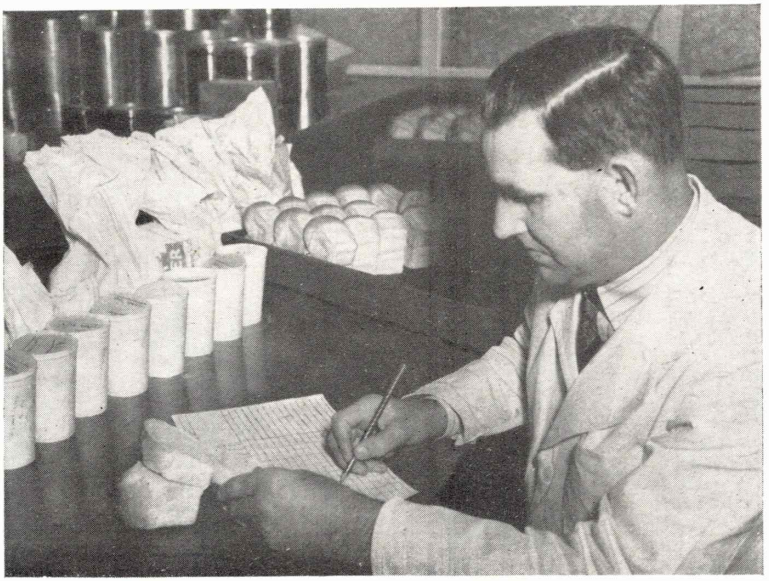
To conserve vitamin C in our foods we should observe the following points:

1. Use them as soon after picking as possible. (Home-grown fruits and vegetables are best.)
2. Do not soak vegetables but wash them thoroughly, using several changes of water if necessary.
3. Do not discard sound outer leaves of green and salad vegetables. They are as rich or richer in vitamin C than the inner leaves.
4. Shred the vegetables roughly just before use, but do not cut up finely. Uncut salads are richer in vitamin C than finely-shredded ones.

After preparing the green vegetable as above, it should be cooked as follows:

1. Place the roughly-shredded vegetable in a small amount of *boiling* salted water, put on the lid and bring to the boil again as rapidly as possible. (This destroys the enzyme in the cells which would destroy the vitamin C.) Then continue cooking briskly for as short a time as possible. Ten to twelve minutes' boiling is sufficient for average quantities of most green vegetables.
2. Do not use copper cooking utensils, as copper increases the destruction of vitamin C.

13. Every carcase of meat is inspected to see that it is free from disease (Page 277)



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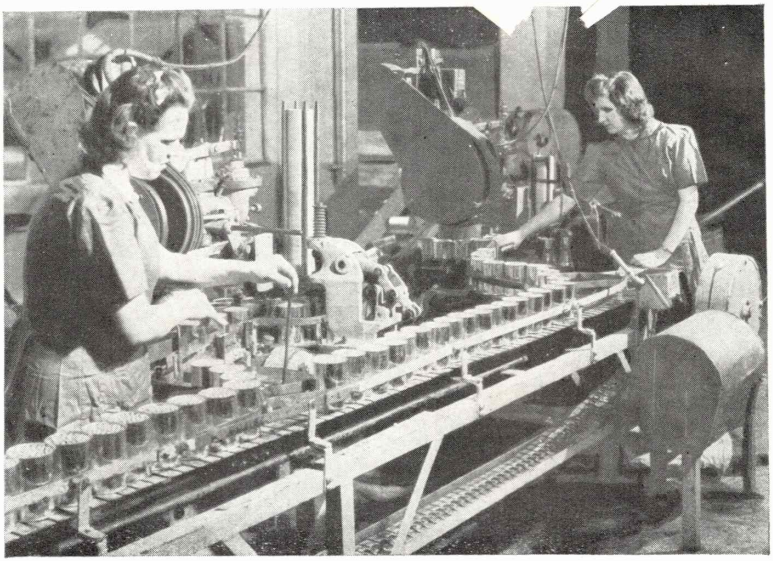
14. Testing flours for bread-making quality at the Wheat Research Institute (Page 287)



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15. The commercial canning of green peas (Page 295)

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16. Diced carrots passing into the dehydrator (Page 317)

3. Strain and serve at once. 'Keeping hot' after cooking results in great loss of vitamin C.
4. Always use the vegetable water for making gravy, soup, etc., as it may contain as much as 80 per cent of the original vitamin C of the vegetable. It is still valuable for vitamin C if kept till the next day.
5. Never use baking soda, as this destroys vitamins C and B_1 and gives the vegetable an unnatural green colour.

The Cooking of Root Vegetables

Root vegetables are richer in starch than green vegetables and therefore require longer cooking. The usual method is to peel them, cut them up, put them into boiling salted water, and cook them briskly with the lid on. In these vegetables much of the mineral matter is just under the skin and so they should be thinly peeled. Potatoes may be cooked in their skins (or 'jackets') in the oven. There is always *some* loss of soluble constituents into the water, which should be used for soup, gravy, etc. Steaming is a method which can be successfully used with root vegetables. It takes longer than boiling but there is less loss of soluble constituents. Roasting in hot fat in the oven is another method used for root vegetables.

The treatment of root vegetables in cooking may be summarized as follows:

1. Avoid soaking. If they must be soaked, use *salted* water.
2. If peeling or scraping is necessary, it should be done as thinly as possible.
3. Steaming and baking retain more mineral salts than other methods.
4. The vegetable water should always be used for soups, gravy, etc.

Since vegetables are cooked in salted water, the losses of mineral salts are not so great as the loss of vitamin C may be. Nevertheless, 10-35 per cent of the calcium and phosphorus and 25-50 per cent of the iron may dissolve into the cooking water. Unless care is taken, as much as 80 per cent of the vitamin C may be lost in the cooking water or destroyed by wrong methods of cooking.

The Cooking of Fruit

Since fruits are valuable chiefly for their vitamin C and mineral salts, they should be eaten raw whenever possible. If cooked, fruit is nearly always stewed in water with or without sugar, or baked.

If a fruit is cooked in wat... break up and become mushy. If it is cooked in a sy... of the fruit is retained to a greater extent. In times of su... ge, as during a war, it was the custom not to add the sugar un... cooking was completed because cane sugar, when boiled with an acid (such as that present in most fruits), is hydrolysed to invert sugar which is not nearly so sweet. However, in normal times, fruits are usually cooked in a syrup of sugar and water. They should be kept covered and cooked for as short a time as possible.

The Cooking of Dried Fruits

If these have not been pasteurized before packaging for the market, they should always be well washed before being used. They should then be covered with boiling water, and left to soak for one to two hours before cooking. (Allow two to four times as much water as fruit.) Do not add sugar till the last few minutes of cooking, as this enables the fruit to absorb water more readily and to become more tender than if the sugar is added at the beginning of the cooking process.

Cooking by Pressure Cooker

High temperatures tend to hasten the destruction of vitamin C, but in the pressure cooker there is no greater loss than by other methods of cooking, *provided the minimal time for cooking is not exceeded.* Experiments on green vegetables for vitamin C, and meats for vitamin B factors, show that pressure cooking is quite as satisfactory as boiling and simmering methods for retention of these vitamins in meat and vegetables. There is insufficient evidence to show that the pressure saucepan allows *greater* retention of the vitamins. For example, in an experiment on the vitamin C retention in potatoes by Van Duyne, Chase and Simpson, the following results were obtained:

	Minutes	Retention
Peeled, boiled	28·6	87%
Peeled, steamed	36·0	86%
Baked	30-50	87%
Peeled, halved, pressure cooker	8	85%

The smaller quantity of water and the shorter cooking time in pressure cooking probably minimize the loss of soluble mineral salts and vitamins.

SUMMARY

Foods are cooked:

1. Because eating certain foods raw is distasteful.
2. To develop flavour and increase palatability.
3. To soften connective tissues and burst the starch grains, so making foods more digestible.
4. To sterilize foods.

To conserve vitamin C in foods:

(a) Raw

1. Use as soon after picking as possible.
2. Do not soak.
3. Use sound outer leaves.
4. Shred roughly just before use.

(b) Cooked

1. Put into boiling salted water and bring rapidly to the boil again, with the lid on.
2. Boil briskly for as short a time as possible.
3. Serve immediately.
4. Use the vegetable water for soups, gravy, etc.

Foods rich in protein should be cooked slowly at a low temperature High temperatures cause the protein to shrink and become tough and indigestible.

Dried peas and beans require soaking before cooking. If water is hard, a little baking soda should be added or the protein will combine with the calcium salts in the water and form insoluble compounds which cannot be softened by cooking.

All vegetable foods containing much starch require long slow cooking to soften the cellulose and to burst the starch grains.

EXERCISE

1. What are the ways in which vitamin C may be lost from foods containing it?
2. To conserve vitamin C in foods, what four points should be remembered in the preparation of vegetables?
3. Give four reasons for cooking foods.
4. What are the effects of heat on the food constituents?
5. What is the difference between boiling and simmering as methods of cooking?
6. What are the aims in cooking meat?

7. Contrast roasting in the oven and stewing as methods of cooking meat.
8. Why does fish require careful cooking?
9. What is the important thing to remember in cooking eggs and cheese?
10. What are the underlying principles in the cooking of legumes?
11. What is the principle underlying the cooking of cereals and all starchy foods?
12. How should green vegetables be cooked to conserve their food value as much as possible?
13. How should root vegetables be cooked?
14. Give four points summarizing the important points to remember in cooking vegetables.
15. What difference does the addition of sugar to stewed fruit make (*a*) if it is added at the beginning of cooking, and (*b*) if it is added at the end?
16. What are the aims in cooking dried fruit, and how is this best done?
17. How does the vitamin C value of foods cooked in the pressure cooker compare with that of foods cooked by ordinary methods? What important point must be observed in the former method?

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The Preservation of Food

SINCE THE DAWN of history man has had a great struggle to preserve enough food to last from one harvest to the next. This is because his food, in one form or another, also nourishes vast hordes of smaller organisms ranging from rats, mice, and insects of various kinds to countless bacteria, yeasts, and moulds. He must early have learned that when protection from rodents and insects was assured, certain foods had better keeping qualities than others and from this point of view, foods may be divided into three groups, as follows:

1. *Perishable foods.* These, without some method of preservation, begin to deteriorate almost at once, e.g. milk, meat, sea foods, and juicy fruits.
2. *Semi-perishable foods.* These will keep for several months without spoilage, e.g. mature potatoes and root vegetables, and some kinds of apples and pears.
3. *Non-perishable foods.* These will keep indefinitely, e.g. cereals and legumes.

The variation in keeping quality is most likely due in the first place to the variation in the amount of water present. Thus, perishable foods have a high percentage; semi-perishable foods have a lower percentage, and in addition a firm skin or covering which also offers protection from outside agents; non-perishable foods have a low water-content and if this is increased the food spoils rapidly.

Food spoilage is due to the action of specific agents which cause physical and chemical changes in the food. These agents are *bacteria*, *yeasts*, and *moulds*, which grow in the food and set up decomposition and fermentation due to the action of enzymes.* The changes

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* Enzymes or ferments are found throughout the animal and vegetable kingdoms. They are substances present in or produced by living cells, but are not alive themselves. They are sometimes called 'organic catalysts', and assist in starting and in speeding up chemical changes in organic materials, e.g. the digestive enzymes change the food eaten into soluble forms; the enyzmes in yeast change sugars into alcohol and carbon dioxide. Before enzymes can act, certain conditions must be present. Briefly these are:
(1) Moisture must be present. (2) Temperature must be suitable: high temperatures destroy enzymes, low temperatures inhibit or delay their action. (3) The medium (or surroundings) must be suitable, e.g. some enzymes require the presence of acid, others of alkali, and so on. (4) The products formed must be removed, or the action will slow up and finally cease.
Each enzyme has a specific action, i.e. it will act on one particular type of material and on no other, e.g. ptyalin in the saliva changes cooked starch into maltose but has no action on other materials.

brought about by moulds and yeasts are seldom harmful. Moulds which grow on foods alter the taste and texture. Yeasts produce carbon dioxide and alcohol in the food and here again the change can readily be detected. Bacteria, on the other hand, though sometimes producing gases and abnormal odours, may also produce toxins which are deadly poisons. No apparent change in appearance, odour, texture or flavour accompanies their formation.

There is little danger in commercially-canned foods, or in home-preserved fruits; but home-preserved meats and vegetables may be harmful. Food which shows any indication of spoilage should be discarded, and all home-preserved non-acid foods should be heated before being tasted. Heating to boiling-point for fifteen minutes will destroy the toxic substance produced by these organisms.

Since most of the perishable foods have a very short 'season' when they ripen and are at their best, they should be bought when they are cheap and plentiful and preserved for times when they are not on the market fresh. In this way the food constituents which they supply, especially vitamins, mineral salts, and organic acids, may be included in the diet and thus help to give flavour and variety and more healthful meals in the winter. To buy foods when they are cheap and plentiful and preserve them for times of scarcity is real economy, e.g. eggs, tomatoes, fruits, and vegetables may all be preserved. Since the destruction of vitamin C is less in the case of acid fruits such as tomatoes and black currants, it is recommended that these be preserved in preference to other fruits.

Now we have learned that enzymes require certain conditions before they can act. Hence, in order to preserve food, we must either destroy the living organisms which cause decomposition or at least slow down their rate of growth, or else alter one or more of the conditions that are needed for enzyme action. The ones we are chiefly concerned with here, are moisture, temperature, and medium or surroundings, for it is by alteration of one or more of these conditions that most methods of preservation depend.

I. Methods Depending on Lowering the Proportion of Moisture

By lowering the proportion of moisture in a food, the growth of organisms and the action of their enzymes are prevented. Moulds require less moisture than either yeasts or bacteria, and thrive in warm, dark, damp places where the air is stagnant.

Dried fruits such as figs, dates, and raisins have been known since ancient times, and in modern times the process of sun-drying has been supplemented or replaced by 'dehydration' plants in which the conditions of temperature and humidity can be carefully controlled. A

great variety of foods may be dried, e.g. fruits, such as prunes, apricots and apples; vegetables, such as potatoes and carrots; and eggs, milk, fish, and meat. (See *Plate 16*).

In the case of fresh fruits and vegetables, it is found that the loss of vitamin C is prevented if the fruit or vegetable is first scalded rapidly to destroy the enzyme which is present in the plant cells. They can then be dried in a current of air, the temperature of which must not rise above 160°F. Commercially, a very small proportion of sodium sulphite is used in the water in which the vegetables are scalded, as it helps to prevent oxidation of the vitamin C. The amount is regulated by law, as too much is harmful to the kidneys. It is too small an amount (two parts per million) to measure accurately for home drying, and should not be used in this case. The vegetables are usually cut into one-eighth inch slices, scalded for one minute, drained, and then dried in a current of air at 140-145°F. They require soaking for about 20 minutes before using, retain the colour (and the carotene), and 35 per cent of the vitamin C of the fresh vegetables. This is retained for some months after drying, especially if the air in the container is replaced by an inert gas such as nitrogen. Commercially-dehydrated vegetables, therefore, supply carotene, vitamin B factors and vitamin C, and are available when fresh vegetables are scarce.

Meat, fish, and eggs can also be dehydrated successfully. Milk is dried by the spray or roller process, and eggs by the spray process.

The nutritive value of dried foods such as meat, fish, eggs, milk, and vegetables is equal to that of the same foods preserved by canning or refrigeration, and may be greater. In the home it is impossible to use such accurate and rapid methods, so the loss of the water-soluble vitamins is greater. Home dehydrated foods should not be relied on as sources of vitamin C. Commercial methods result in some loss of thiamine but the riboflavin and nicotinic acid, as well as carotene, are not appreciably altered.

II. Methods Depending on Changes of Temperature

Since growth and enzyme action are retarded by cold and prevented altogether by heat, use is made of both methods for the preservation of food. In chilling, freezing, and cold storage, the action of enzymes and the growth of moulds are prevented by the low temperatures, while in sterilizing and pasteurizing, the active agents are inhibited in action or totally destroyed. That freezing is an effective method of preservation is shown by the fact that mammoths, huge prehistoric ancestors of the present-day elephant, estimated to be 20,000 years old, have been found in a perfect state of preservation in Siberia encased in thick ice. Most foods will keep

almost indefinitely in cold storage and low temperature methods of preservation enable New Zealand to export vast quantities of beef, mutton, lamb, cheese, and butter, to Great Britain, a distance of 12,000 miles, and involving passage through the tropics.

In the modern 'frozen foods' process, the food is frozen rapidly by exposure to brine or cold air at very low temperatures, which forms very tiny ice crystals within the food and does not break the cells, as does the cold storage process. The latter is a slower process, and allows the formation of large ice crystals within the cells which are often ruptured in the process. Fish, fruit, and vegetables may be treated by the quick freezing process. Fruit is covered with a 50 per cent solution of sugar and frozen at −20°C to −45°C (or −4°F to −50°F) and then stored at about 0°F. Vegetables are scalded, cooled, frozen, and then stored at about 0°F. If they are put straight into the hot fat or boiling water in which they are to be cooked, and brought rapidly to the cooking temperature, their nutritional value does not deteriorate. Slow thawing, on the other hand, results in rapid loss of vitamin C. Generally speaking, the nutritional value of such frozen foods is equal to that of fresh foods cooked by ordinary processes—and may be higher, since they are often picked and processed 'on the spot'.

Ordinary cooking causes the destruction of living organisms and of enyzmes present in foods, and so cooked food keeps longer than uncooked food. We have seen* that all bacteria and their spores can be killed by heating to boiling point, on three successive days, and allowing to cool in between. This process of *sterilization* has been largely replaced commercially by a simple heating to 120°-125°C, which will kill the spores as well as the bacteria.

III. Methods Depending on Unsuitable Medium

1. Removal of oxygen. Most organisms causing decay require oxygen, and in the common methods of preserving eggs the oxygen of the air is excluded and so the eggs do not go bad. The egg-shell is porous and unless it is sealed, bacteria can gain entry and cause the egg to decay. Sealing may be done either by coating the eggs with grease of some sort, or else by immersing them in a solution of 'water glass' (sodium silicate).

2. Since the surroundings must not contain too much of any particular substance, methods of preserving which use high concentrations of acids, salts, etc. have been evolved. These substances act as antiseptics in that they prevent the growth of organisms, and the high concentration prevents enyzme action. Such methods are:

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*See *General Science*, p. 354.

a. Use of acid, e.g. vinegar, in preserving vegetables, e.g. pickles, etc.

b. Use of salt, as in preserving vegetables, meat, and fish. Wood smoke is also used sometimes for meat and fish.

c. Use of sugar and high temperature, as in jam-making and fruit-preserving.

d. Use of 'preservatives', i.e. chemical substances which prevent the growth of micro-organisms. These are sometimes harmful and should be used with great care, if at all. For example, borax used as a preservative for milk or cream will mask the sourness which is the natural indication that the milk is no longer fresh; but it does not prevent decomposition of the protein, which will have far more harmful results (poisoning) if such food is eaten. In the same way sulphites, used as meat preservatives, will remove the bad smell and so perhaps hide the fact that the meat has begun to decay.

The use of preservatives, commercially, is strictly controlled and only those substances specified in the New Zealand Food and Drugs Regulations 1946 and amendments, may be used. These regulations are specially designed to prevent contamination and adulteration of food. If a preservative is used in any food, the amount must be clearly printed on the label of the package. The following substances may be added to food without being declared: acetic acid, potassium or sodium nitrate, salt, spices, sugar, vinegar, or wood smoke. Preservatives most commonly used are sulphur dioxide and sulphites, and benzoic acid and benzoates.

Too much of any given constituent may be regarded as adulteration, e.g. if butter contains more than 16 per cent water, the excess is regarded as adulteration; so also is more than two per cent starch in icing sugar, less than 45 per cent cocoa fat in cocoa, less than 60 per cent reducing sugars in honey, and so on. Thus milk must not contain less than 3¼ per cent milk fat and not less than 8½ per cent milk solids other than fat. Milk of this composition has a relative density of 1.029 - 1.034 (p. 137). But since milk is relatively heavier than water, the addition of water to milk will cause a lowering of the relative density. On the other hand, milk fat is lighter than water, so removal of some of the cream increases the relative density of milk. Hence a dishonest vendor may adulterate the milk by removing cream and adding water, and still show the correct relative density. The addition of water to milk is best detected by using a special thermometer called a Beckmann thermometer which registers hundredths of a degree Centigrade. The average freezing point of a very large number of samples of milk is found to be

−0·54°C, and if the freezing point of any sample tested is appreciably higher than this, it is usually an indication that water has been added.

THE NUTRITIVE VALUE OF PRESERVED FOODS

Several classes of preserved foods have already been dealt with in previous chapters, e.g. dried and condensed milk and dried fruits. In the cases of canned or bottled fruits or vegetables, the vitamin values of those preserved by commercial methods are higher, generally speaking, than those of home-preserved products. This is because methods in which the oxygen of the air is excluded have been developed, and, in these, destruction of vitamin C is lessened. Nevertheless, canned or bottled foods cannot equal in flavour and palatability fresh home-grown products. There is a monotony of taste about them if they are used too often in the diet. Their protein, carbohydrate, and fat are affected as in ordinary cooking; mineral matter, if extracted, is retained in the liquid which is usually served with the food. But it is the vitamin content which is most liable to be altered. Vitamins A and D, as we have said, are little affected by cooking or processing. Vitamin C is decreased in canning, dehydrating and quick freezing, though such foods may still retain more than so-called 'fresh' foods bought after a day or two in a shop and then badly cooked. Riboflavin and nicotinic acid are not reduced much by preserving but thiamine may be reduced considerably by the presence of sulphite or by the high temperatures that are used in meat processing. In the same way, the thiamine of cereals may be reduced by the high temperatures required for the preparation of certain prepared cereal foods.

Thus methods of preservation do lower the vitamin C and thiamine content, as compared with the fresh foods; but since processing enables us to save large amounts of food that would otherwise be wasted, its use is of great value economically. Provided that bottled and canned foods are not relied on entirely to supply these vitamins, they are a valuable adjunct to the diet especially in the winter, enabling us to have flavour, colour, and variety in our meals when the fresh foods are not available. The processing of food enables a glut of food in one country to be exported to other countries in need of it, and it is an industry which is likely to increase if the raising of food standards and the prevention of malnutrition are to be undertaken on a world scale. Imagine all knowledge of canning destroyed, all knowledge of cold storage removed, all methods of artificial dehydration eliminated, and all chemical preservatives unknown—and you will realize in some measure the value and extent of food preservation at the present day.

THE HYGIENIC HANDLING OF FOOD

At the beginning of this chapter we said that food had to be protected from myriads of small organisms which would live on it and so make it unfit for human consumption. Since much of our food is now prepared for us commercially, the national as well as the domestic aspect of food handling is of great importance. Some of the municipal services that are concerned not only with the general health of the community but also to ensure that food is produced and prepared for the market under clean conditions, are: (1) provision of an adequate and healthy water supply, (2) pasteurization of milk (*Plate 9*), (3) adequate removal of garbage and rubbish, and (4) sanitary disposal of sewage. All places where food is prepared for the market, such as slaughterhouses, bakeries, and fisheries, as well as all shops where food is sold, and all eating places, may be inspected for cleanliness of operation and adequate storage and protection of food that is to be sold to the public, directly or indirectly. A continual war must be waged against the hordes of organisms that would invade and ruin our food if we were not continually on guard against them.

Besides organisms which would destroy our food by living on it themselves, pathogenic bacteria of various kinds, as well as parasitic worms, may get into food and thus cause disease in man. Some of the former have already been mentioned in connection with the pasteurization of milk. Now there are people, who, having recovered from an attack of an infectious disease, still carry the germs of the disease in their nose, mouth, or intestine without showing any signs of the disease, and are capable of passing on the germs to others. Such people are called 'carriers'. Perhaps the most dangerous disease that can be passed on in this way is typhoid fever. The germs are present in the large intestine and leave the body in the excreta. Careless personal habits are then the means of the germs getting on to the hands and thence to food. If the carrier happens to be a worker in a food factory, food shop, dairy or kitchen, he may infect food that others will eat, and in this way epidemics have started. Consequently, personal cleanliness is a most important factor in the hygienic handling of food. 'Carriers' should never be allowed to handle food—they should not be allowed to work in abattoirs, bakeries, dairies, fish shops, market gardens, or any place where they would handle food for use by other people. It should be realized that in diseases of this kind caused by pathogenic bacteria, the infecting cause is *always* a human case or carrier.

Flies, mice, and rats can all carry disease germs from infected matter to food, hence all measures against these vermin should be

taken. Bluebottle flies are a great cause of food spoilage in hot weather. If food is not left lying round, flies, mice, etc. will have nothing to eat, so that strict attention to the disposal of refuse in the home, as well as in the shop and factory, will help to eliminate these pests. The plentiful use of hot water and soap in the kitchen, the screening of all food from flies and its protection from rats and mice, should be regarded as necessities in every home and in every place where food is handled. The need for personal cleanliness in matters such as the washing of hands before handling food, and after visits to the lavatory, are points whose importance should be understood by all. The modern refrigerator for use in home, shop and factory, is a great advance both in keeping food fresh by retaining it at a low temperature, and in protecting it from insects and rodents.

SUMMARY

Food must be preserved:

1. from rats, mice and insects;
2. from yeasts, moulds, and bacteria.

Importance of food preservation.

1. A glut of food at one time of the year may be saved for times when such foods are not available fresh.
2. It enables us to have colour, flavour, and variety in our meals in winter.
3. It ensures the supply of a certain amount of vitamins, when fresh foods are hard to obtain.
4. Countries which have a surplus of food can export it to less fortunate countries.

Chief methods of food preservation:

1. Drying or dehydration—prevents growth of organisms and action of enzymes.
2. Change of temperature—cold temperatures inhibit enzyme action and the growth of organisms, e.g. freezing, cold storage. High temperatures destroy both enzymes and organisms, e.g. cooking, sterilizing, pasteurizing.
3. Unsuitable medium.
   (a) Removal of oxygen—as in preserving eggs.
   (b) Too much of certain materials, e.g. vinegar, salt, sugar.
   (c) Chemical preservatives such as sulphites.

Nutritive value of preserved foods: Generally speaking, commercially-preserved products have higher vitamin values than home-preserved products. Vitamins A and D, riboflavin, and nicotinic acid are little affected by food processing; but vitamin C and thiamine may be reduced by oxidation, high temperatures, and the presence of sulphites. Nevertheless, preserved foods, both dehydrated and canned, may contain as much or more of these vitamins as so-called 'fresh' foods, badly cooked. They also supply flavour, colour, variety, mineral salts, and organic acids in our meals in winter months.

Hygienic handling and storage of food are most necessary to prevent contamination both by insects and rodents and to protect it from pathogenic bacteria. Certain diseases may be transmitted through food, e.g. milk-borne diseases. 'Carriers' must never work in places where food is handled for use by others.

EXERCISE

1. Give a classification of foods according to their water content and keeping quality.
2. What are the causes of food spoilage?
3. Write an account of the dehydration of foods. How does this process affect the vitamin value of the foods?
4. Write an account of food preservation by methods depending on change of temperature.
5. Write an account of food preservation by methods depending on a medium unsuitable for the growth of bacteria.
6. What are the general effects of preservation on the vitamin values of foods so treated?
7. Name some of the municipal services that are directly concerned with the production and preparation of *clean* food for the market.
8. What is meant by the term 'pathogenic' bacteria? How may such bacteria get into human food?
9. Besides man himself, what other agents may transmit dangerous germs to food?
10. List six steps that should be taken by all, to ensure protection of our food from spoilage by living organisms.

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The Fate of Foodstuffs after Absorption. Metabolism

WE HAVE LEARNED what our food contains and what happens to these constituents during digestion, and how they are absorbed into the blood to be used according to the body's needs. But our study of nutrition does not end here. We must also learn something of what happens to these food products in the tissues themselves. We know in a general way that they are burned or oxidized in the tissues to produce heat and energy, and that waste products, carbon dioxide, water, and urea are formed in the process. The sum of the building-up and breaking-down processes that go on in the body is called *Metabolism.* That is, metabolism is a term covering all the processes concerned in the building up of protoplasm, the activities that go on in the cells themselves, and the breaking-down of materials in the cells into simpler products. It covers all the processes involved from the time food enters the mouth until its residue is excreted—the growth and repair of tissues, the release of energy in the form of heat, muscular and nervous activity, and so on. It is promoted by oxygen, hormones, enzymes, vitamins, and the nervous system.

We think of the body as being at complete rest when lying perfectly still and relaxed in bed, but work is going on all the time. The heart never stops beating nor the blood from circulating, we breathe all the time, our body temperature always remains practically the same, tone is always present in our muscles, and in every cell, the processes of internal respiration, assimilation, secretion, excretion, building up and breaking down of protoplasm go on all the time. In all these processes energy is essential and it is derived primarily from the food brought to the cells in the blood and lymph, and is finally liberated as body heat. The smallest amount of energy needed for these vital processes of the body, when at complete rest in bed, is called the 'irreducible minimum' of energy needs. It is found by measuring the amount of oxygen used by the body when at complete rest in bed, twelve to fourteen hours after the last meal. Measurement of the amount of oxygen used by the body in a given time shows how much food material has been oxidized and therefore

how much energy has been used up in that time. This measurement is known as the 'basal metabolism' or *Basal Metabolic Rate* (BMR) and is often made use of by doctors in diagnosing disease.

The average figures for persons of different height, weight, age, and sex have been found from a great many individual measurements and if there is a big variation from the average, the doctor suspects certain abnormal conditions in the patient (e.g. an overactive thyroid gland will raise the basal metabolic rate of the individual). The rate of oxidation in the body is measured in *Calories.**

It has been found that the basal metabolic rate varies with the height, age, weight, and sex of the individual. A man of 11 stone, lying at rest, needs about 1685 Calories every twenty-four hours, simply to keep his vital processes going. Any movement that he makes, no matter how small, increases his need for energy, so that the more active a person is, and the harder physical work he does, the more Calories he needs, or the greater his energy requirement. It is observed that a tall thin person often has a higher metabolic rate than a short fat person of the same age, sex, and occupation. This means that the tall thin person uses up more of his food to meet his energy needs than the short fat person, partly because he has a larger body surface in proportion, and therefore loses more heat to his surroundings. It also partly explains why tall thin people do not always put on weight even when eating plenty of food, and why short, stout people may remain fat even though eating a smaller quantity of food.

The Metabolism of Carbohydrates

The carbohydrates having been digested and absorbed in the form of simple sugars, are carried by the portal vein to the liver. But the blood leaving the liver contains only the normal amount of glucose present in blood (usually a little less than 0·1 per cent). The liver retains a considerable part of the glucose absorbed after a meal and releases only a certain amount into the blood. It is stored in the liver and to a less extent in the muscles, in the form of glycogen. The glycogen is constantly being reconverted into glucose, which is oxidized in the cells to yield heat and energy. The amount of carbohydrate that can thus be stored as glycogen is limited, and any excess carbohydrate is changed to fat and stored in that form.

The oxidation of glucose is influenced by the hormone insulin, and

* One Calorie is the amount of heat required to raise the temperature of 1 Kilogram of water 1° Centigrade. Note that the word is spelt with a capital 'C'. This unit is 1000 times a small calorie—the amount of heat needed to raise the temperature of 1 gram of water 1°C. The large Calorie is the one used in books on nutrition, and it should always be written with a capital letter.

cannot take place without it, while the vitamin B factors, thiamine, riboflavin, and nicotinic acid are also concerned with this process. The final products of the metabolism of carbohydrate in the body are carbon dioxide and water.

The Metabolism of Fats

The exact way in which fats are absorbed is not clear, but it is believed that they are emulsified in the small intestine and then split up into their constituent fatty acids and glycerine, absorbed in this form, and then re-formed into fats in their passage through the walls of the villi into the lacteals. Fats must then pass via the lymphatic vessels to the venous blood-stream and so do not pass directly to the liver as do carbohydrates. From the blood-vessels of the general circulation, fats pass into the tissues, and are stored in various parts of the body such as the layer of connective tissue under the skin (the 'subcutaneous layer'), and round the kidneys and many other organs. These deposits are called upon in times of hunger. Fat is carried from them to the liver and broken up into its fatty acids and glycerine. The glycerine can be used for energy purposes, as can glucose, and yields carbon dioxide and water. The fatty acids are finally broken down into simpler substances which enter the bloodstream, where, together with the glucose derived from carbohydrates, they are ready for oxidation. So long as there is plenty of glucose, this oxidation proceeds; but if glucose is not available, poisonous products may be produced, resulting in headaches, vomiting, and malaise. These poisonous products are not formed if there is adequate glucose being oxidized, thus showing the need for carbohydrate, as well as fat, in the diet.

The Metabolism of Proteins

The amino-acids resulting from the digestion of proteins are absorbed into the bloodstream, and, like the simple sugars, are carried direct to the liver. They are able to enter the bloodstream from the liver, and be used for tissue building and repair, the preparation of hormones and enzymes, and so on. If more protein is eaten than is needed for these purposes, or if glucose is not present in the liver cells, the amino part of the amino-acids is changed into the waste product urea, and is lost in the urine. The remaining part of the amino-acid is changed to glucose and used for energy purposes as explained above.

In fasting and starvation, body proteins may thus be broken down to provide heat and energy; but the body draws on its own protein for energy only so long as the fuel value of the total food is insufficient for this purpose. Because of this fact, carbohydrates and fats

are said to have a *protein-sparing action*, i.e. they, and not protein, will always be used to provide energy in the body so long as there are any of them present, thus leaving the protein for other purposes, such as growth and repair of the tissues and so on.

THE CALORIC VALUE OF FOODS

Now we have seen that the oxidation of food in the body is the source of its heat and energy. The amount of heat that any given food will yield can be accurately measured and in this way we are able to find its caloric or fuel value. *The caloric or fuel value of a food is the number of Calories a given weight of it will yield on oxidation.* It is usually expressed in Calories per 100 grams or Calories per pound.

The caloric value may be found in two ways, (a) directly, and (b) by calculation.

(a) *Direct Method.* A weighed amount of the food is placed with a supply of oxygen under pressure (to ensure complete oxidation), in a heavy steel container called a *Bomb Calorimeter*, which has a heavy screw-on lid. The whole is then placed in a weighed amount of water of known temperature, and the food is ignited by means of an electric spark. It burns and gives out heat to its surroundings. From the rise in temperature the amount of heat given out by the food can be calculated. Figures have been obtained from the bomb calorimeter for oxidation of pure carbohydrate, protein, and fat, which are the only food constituents that yield Calories. These are:

Carbohydrates	4·1 Calories per gram
Fats	9·3 Calories per gram
Proteins	4·3 Calories per gram

(b) *By Calculation.* Conditions in the human body do not allow for such complete oxidation as in the bomb calorimeter, and after allowance has been made for digestive losses, etc., the following values, known as the *Physiological Fuel Values* of the food constituents, are used as the basis for finding the fuel value, by calculation, of any food whose percentage composition is known:

Carbohydrates	4 Calories per gram
Fats	9 Calories per gram
Proteins	4 Calories per gram

Thus, the caloric value of 100 grams of a food of known composition is found simply by multiplying the percentages of carbohydrate and protein by four, and of fat by nine.

For example: To find the caloric value of milk of the following percentage composition: water 87·25, protein 3·30, fat 4·0, lactose 4·75, and mineral matter 0·7—

Calories from carbohydrate	$= 4{\cdot}75 \times 4 =$	19·00
Calories from protein	$= 3{\cdot}30 \times 4 =$	13·20
Calories from fat	$= 4{\cdot}00 \times 9 =$	36·00
$\therefore$ Calories from 100 grams of milk	$=$	68·20

If the fuel value per pound is required, proceed as above and then multiply by $\frac{453{\cdot}6}{100}$ since there are 453·6 grams in 1 pound.

The following are a few examples of the approximate caloric value of some common foods:

	Calories		Calories
1 oz flour	100	1 apple (4 oz)	48
1 oz oatmeal	106	1 banana (3 oz)	51
1 oz dripping	253	1 slice bread	100
1 oz butter	210	1 c raw cabbage	20
1 oz cheese	118	8 dates	150
1 oz sugar	112	1 lamb chop (4 oz)	300
½ pint milk	185	1 potato (4 oz)	84
1 whole egg (1¾ oz)	70	1 oz walnuts	87
½ c cooked spinach	20	1 oz marmalade	72
1 oz milk chocolate	151	4 oz av. lean meat	340
1 oz peanut butter	158	4 oz fat bacon	404

We have seen that only carbohydrate, protein, and fat of the food constituents can yield Calories when oxidized in the body; consequently foods which are rich in one or more of these constituents are said to have *high fuel value* or *high caloric value*. Examples of foods with high fuel value are fats, cereals, cheese, nuts and legumes. These, you will remember, are foods with a fairly low proportion of water, On the other hand, foods which have a high proportion of water will have a low proportion of solid constituents, and so will be of low caloric value, but such foods are often rich in water-soluble vitamins, mineral salts, and cellulose, and for these reasons have a *high nutritive value* (sometimes called high dietetic value), e.g. fresh fruits and green vegetables. Be sure you understand the difference between these terms, caloric or fuel value and nutritive or dietetic value. Caloric value depends on the amount of carbohydrate, protein, or fat present. Nutritive value depends on the presence of *any of the seven essential food constituents* in appreciable amounts. Thus,

the nutritive value of cereals is due chiefly to the presence of a large amount of starch which gives them a high caloric value. Fresh fruits have a low caloric value, but because of their vitamin C content their nutritive value is high.

HOW MUCH FOOD?

The next question to be considered is how much food we should eat in order to provide our bodies with the right amount of food for health. The total amount of food required is proportional to the amount of energy expended, i.e. it must supply all our energy needs, together with materials for the growth and repair of the tissues. *Appetite* is a rough guide to the amount of food to eat, but under modern conditions, appetite is partly artificial and is regulated rather by habit than by physiological needs. We eat at 'meal hours' whether we are hungry or not; delicious food tempts us to eat too much, dull food too little; hurry, worry, and over-tiredness take away the appetite so that food is not eaten when it should be. A grown-up person can check the reliability of his appetite by weighing himself regularly, say, twice a year. If he has stopped growing (say after twenty-five years of age) and is losing weight, either too little food is being eaten in proportion to the energy needs, and the body is burning up its own substance to meet the demands for fuel, or there is a wasting disease present. If he is increasing in weight, his food intake is greater than his energy needs. The healthiest people do not gain in weight after they are fully developed physically. Some life insurance companies deduce from their statistics that the weight of the healthiest adults does not exceed two pounds to each inch of height.

However, for children, adolescents, and young adults up to the age of about twenty-five years, a large appetite is perfectly normal. They are growing, and should show a gradual increase in weight, and if they are leading a normal active life of work and play, large amounts of energy-giving materials are needed. By the age of twenty-five, or before that for many people, growth has stopped, and then food is required for repair and energy purposes only—for maintenance, not for growth. Factors which influence the food needs of the individual are climate, age, sex, and occupation (whether the work done is active or sedentary). For example, the more energetic or physically active a person is, the more fuel food he needs. Thus a farmer, busy outdoors all day, needs more total food than an office worker sitting at a desk. People living in cold climates need more heat-giving foods than those living in temperate or hot climates, e.g. the Eskimos eat large amounts of whale and fish oils but these would be too heating, as well as distasteful, to people living in warmer parts of the world.

A man usually eats more than a woman because he has a bigger body. Old people do not need as much total food as younger ones because they are less active.

Now good nutrition requires that each person shall have such foods as will keep him in a state of *Optimum Nutrition*, i.e. a state of nutrition which cannot be improved upon by any change in diet —without at the same time becoming fussy or a faddist, adding up the Calories, or thinking about the vitamins and mineral salts in everything he eats. In *Dietetics*, which is the application of the knowledge of nutrition in the treatment of disease, it is often very necessary to count the Calories and know the exact amounts of the different constituents present in a given diet. Such requirements do not come into the scope of your work.

Actual Food Requirements

The basal metabolism of the body requires 1600-1700 Calories, and the amount needed above this depends, as we have said above, on the age, occupation, climate, and sex. Figures of dietary studies show that in New Zealand the average caloric value of the daily diet, in 1949, was 3400, in Great Britain it was 3030, and in India 1620. You can see that in India this is below even the basal requirement (for an eleven-stone man). What do you think the effects of this are on the population as a whole?

The following are the average requirements which are recommended to provide optimum nutrition. It should be realized that even though the total Calories are sufficient, a diet may not necessarily be adequate in nutritional value; but a diet which does not supply even enough Calories, is likely to be very deficient in other essential constituents.

1. Calories. The total food eaten should supply 2000-3000 or more Calories per day, depending on age, occupation, climate, and sex.
2. Protein foods of good quality to supply 10-15 per cent of the total Calories. This is roughly 2½ ounces of pure protein.
3. Fats to supply 20-35 per cent of the total Calories. This is 3-4 ounces for people in temperate climates.
4. Carbohydrates to supply 50-70 per cent of the total Calories.
5. Calcium.* 0·8 gram per day for an adult and 1·3 grams for a girl of 13-20 years.
6. Phosphorus. One gram per day for a child and 1·5 grams for an adult.

*Amounts recommended in the National Research Council's Recommendations, 1953.

7. Iron. 12 milligrams a day for an adult.
8. Iodine. 150-300 micrograms a day for an adult (1,000,000 micrograms are equal to 1 gram).
9. A liberal supply of all the vitamins for both children and adults.

The material given in Chapter 23, *General Science*, should now be thoroughly revised, particular attention being paid to the New Zealand Daily Dietary Pattern since by following this pattern, in meal planning, the amounts of the different constituents recommended, will be provided.

Eating to Gain or Lose Weight

Having learned something of the food needs of the body, and of the caloric value and metabolism of those foods, we must now consider briefly the question of eating to lose weight or to put on weight. Any form of strict 'dieting' should be undertaken only under the supervision of a medical practitioner, and does not come within the scope of this book. The composition of the diet affects the whole working of the body, and unless the effects of certain changes in the diet are understood, the results may be harmful. This applies particularly to certain 'slimming diets', in which, say, all carbohydrate or all fat, is rigidly excluded. We have seen that there are seven essential constituents of food and that these must all be provided in certain amounts, daily, if bodily health is to be maintained.

In general, slimming diets contain less carbohydrate and less fat than the normal diet; but it is essential that the protective foods be not omitted or even reduced. Similarly, fattening diets contain more carbohydrate and more fat than the normal diet; but the protective foods must also be supplied in adequate amounts. In the first case, the stores of fat in the body must be gradually reduced; and in the second, more food than is needed to meet the everyday demands of the body for fuel for heat and work must be consumed, so that the surplus may be laid down in reserve and thus cause an increase in body weight.

The overweight person is nearly always over-fat, and this means that the individual concerned is eating more food than is required for the amount of energy he expends. Of course, some people have a 'tendency' to overweight, and this may be due to several factors such as appetite, constitutional differences, and the effects of the endocrine system (i.e. of the secretions of the endocrine glands). Whatever the influences, the control of body-weight in the individual is essentially a matter of proper balance between what is eaten and what is used in the metabolism of the body.

The remedy for overweight is to eat less, to burn more (i.e. to take more exercise), or both. The taking of thyroid preparations or any other drug which has the effect of increasing oxidation in the body should never be indulged in except under strict medical control, as it may be dangerous to the individual concerned. For most people, reduction in weight can be achieved by eating less of the foods that are not important sources of protein, mineral matter, and vitamins, i.e. of the 'supplementary energy foods'. Such reduction should be a long-term process—to aim at quick results may well be too drastic a process for the health of the person concerned.

Conversely, increase in weight can be achieved by increasing the total amount of food eaten—the increase being in protective as well as supplementary energy foods.

EXERCISE

1. What is meant by the term 'metabolism'?
2. What is meant by the 'Basal Metabolic Rate'?
3. What is a Calorie?
4. Give a brief account of the metabolism of carbohydrates.
5. Give a brief account of the metabolism of fats.
6. Give a brief account of the metabolism of proteins.
7. What is meant by the 'caloric value of a food'?
8. Outline the method for finding the caloric value of a food, using the bomb calorimeter.
9. What does the term 'physiological fuel values' of the food constituents mean? What are these values?
10. Using the physiological fuel value for your calculations, find the caloric value of:
    (a) 100 grams milk (percentage composition on p. 275).
    (b) 1 lb butter (percentage composition on p. 275).
    (c) 1 lb lean meat (percentage composition on p. 278).
    (d) 100 grams white bread (percentage composition on p. 287).
11. Explain carefully the difference between fuel or caloric value and nutritive or dietetic value.
12. What four factors influence the food needs of the individual? Explain each briefly.

13. What is the general relationship between body weight and the amount of food eaten
    (a) in a person who is still growing,
    (b) in a person who has stopped growing?

14. What does the term 'optimum nutrition' mean?

15. Explain the terms 'protective' and 'supplementary energy' foods, with examples of each according to the League of Nations Technical Commission's classification.

16. Describe the 'Daily Dietary Pattern for New Zealand', and say what the purpose of this pattern is.

17. In general, how do diets for (*a*) slimming and (*b*) fattening differ from a normal diet?

18. In what way should such diets resemble the normal diet?

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Meal Planning

THE ORDINARY PERSON has no need to count Calories or to calculate the amount of vitamins or mineral salts his meals contain. A safe rule to follow in planning meals is to make sure that the protective foods are supplied, and the Calories will take care of themselves. The housewife should regard the planning of a daily menu which will provide the correct kind and amount of food for every member of her family, as one of her most important duties. Planning meals in advance produces the best results as far as variety and proper balance are concerned, and allows time for the buying of ingredients, etc. which will be required. Planning meals ahead does not mean that the plan must be rigidly followed. Latitude must be allowed for the use of left-overs, the possibility of not being able to buy certain foods because of shortage of supply or rise in price, extra guests, and so on. Meals may be planned a week or even a fortnight ahead, and only slight alterations, due to such circumstances as have been mentioned, will need to be made.

An understanding of the value of each article of food in the diet is essential for the planning of 'balanced meals', i.e. meals which will provide all the essentials for optimum nutrition in proper amounts for all members of the family, and which are at the same time attractive and appetizing. What you have learned in your lessons on nutrition should have given you an understanding of the nutritive value of different foods, so that if one item planned for is not available you will know what to substitute for it. Meal planning should result in better all-round nutrition, for the houswife can check up on her plan and see whether her family is really getting enough of each of the essential constituents. It is not likely that the total food will be insufficient; but there may be a shortage of some factors or too much of others.

MENU BUILDING

In drawing up a meal plan, the following points should be considered:

1. The menu should be *well balanced* from the nutritional point of

view, i.e. each of the day's meals should contain protective foods as recommended by the League of Nations Technical Commission, with supplementary energy foods in addition, to make up the total food required by each individual. The total food needs depend on:

(a) *The ages* of the members of the family. Children of different ages require different quantities of food. Adolescents require more first-class proteins, vitamins, and mineral salts than adults because they are growing rapidly. Their energy needs are also great.

(b) *The occupations* of the adult members of the family. Those engaged in active physical work use up more energy and so require more fuel foods than sedentary workers. For example, the housewife busy all morning at housework and perhaps doing her own washing, etc. may well have a greater need for energy-yielding foods than her husband who has a sedentary occupation, e.g. in a bank.

(c) *The climate and season.* In cold climates and in cold weather more of the food is used in maintaining the body temperature and we are able to eat more fats. In hot summer weather there is less loss of body-heat to the surroundings and so less heat-giving foods are required and more of the cooler refreshing foods such as fruits and vegetables are desired.

2. The *cost* of food in relation to the family income must be considered.

(a) Meals may be planned on an elaborate and expensive scale or on a simple and economical scale, and both may provide the essentials for adequate nutrition.

(b) Remember that foods grown out of season are always expensive and often lacking in flavour. The highly-priced fruits and vegetables at the beginning and end of the season are not for those on ordinary incomes: their place should be taken by more reasonably-priced foods of equivalent food value.

(c) Do not serve too many kinds of food at one meal, but choose foods which 'go well together'.

(d) Arrange the preparation to save time and fuel. Use the oven for more than one thing at a time.

3. *Variety.* In well-planned meals, at whatever level, there is always plenty of variety. Variety in meats, vegetables, fruits, and other foodstuffs, means that there is less likelihood that any of the essential constituents will be left out of the diet. In this connection, the food likes and dislikes of the members of the family must not be overlooked. They may make the balancing of the menu more difficult.

4. *Suitability to season and day.* This aspect has been touched on above. The meal plan must be flexible, so that minor alterations may be made to suit our changeable climate, e.g. tomato soup could replace a cold salad for lunch if the weather turns cold.

5. *Digestibility.* The daily menu should not contain more than one food which is difficult to digest. For example, pork, nuts, fried foods, and pastry are included among the 'more difficult to digest' foods.

6. *Colour, flavour, and texture* of the foods. Meals can be made very attractive by using foods together whose colours harmonize. For example, the green of spinach and the orange of pumpkin are attractive served together, but tomatoes and beetroot clash. Attractive appearance stimulates the flow of digestive juices and so aids digestion. Meals lacking in colour are generally dull, e.g. fish, white sauce, and mashed potatoes; or cauliflower and white sauce in the first course followed by a plain milk pudding is an unattractive sequence. Avoid serving meals which are insipid in flavour; but do not mask natural flavours by the over-use of strong condiments. Vary the texture of the foods served at different courses of the same meal, so as to provide variety in this way as well as in flavour.

7. *The manner of serving* should be simple, attractive, varied, and always spotlessly clean.

8. *Time and equipment available.* The meal plan must take into account the other manifold tasks of the housewife, so that on washing day, for example, she does not have to spend a long time in the kitchen preparing dishes that need a great deal of attention. She must also plan meals that she has the necessary equipment to prepare, cook, and serve correctly.

In addition to the above general rules the following practical points should always be kept in mind in meal planning:

(a) Use less white flour and more wholemeal.
(b) Use more potatoes in place of some of the cereal dishes.
(c) Avoid excessive use of white sugar. Do not yield to the temptation to serve many sweets and cakes.
(d) Use more milk, including skim milk, which is a good food.
(e) Use some fresh raw fruit or vegetable every day.
(f) Use liver once a week and fish once a week in place of so much meat; use more cheese for the same purpose.
(g) Use iodized salt for all purposes in cooking as well as on the table.
(h) Plan meals for regular times and have them at those times. This aids digestion, teaches the family to be prompt, and preserves the cook's disposition.

Steps in Menu Building

1. Plan for a week or more at a time.

2. In planning meals for each day, it is a good idea to start with the dinner, which forms the main meal, and to build up the other meals from it, first lunch and lastly breakfast. Remember that between-meal 'snacks' for an adult, e.g. a biscuit with the morning cup of tea, sweets eaten at the movies at night, and 'play lunches', etc. for children, add to the total Calories of the diet, and should not be disregarded in thinking of the total food. As previously mentioned, a Calorie is a Calorie, at whatever time of the day and in whatever form the food is taken.

3. When the week's menu has been prepared, check it against the rules for menu building already given to see that they have been adhered to.

MEAL PATTERNS

1. Dinner Menus

Simple dinner menus are planned in this order:

(a) the meat or protein dish,
(b) potatoes and vegetables,
(c) soup, if it is to be served,
(d) dessert.

EXERCISE Following the above rules, plan simple dinner menus for a day in summer and a day in winter.

Here are two examples of well-balanced *dinner menus*, followed by three ill-balanced ones, to give you some idea of what is desirable and what should be avoided:

(a) Roast lamb and mint sauce, green peas, carrots and new potatoes; spanish cream and stewed apricots.
(b) Cold ham, lettuce salad with chopped hard-boiled eggs and cold green peas, raw tomato and new potatoes; bread custard with sultanas.
(c) Roast pork, roast potatoes and pumpkin; suet pudding and cream. (There is too much fat in this meal. The addition or substitution of a green vegetable, and the replacement of the suet pudding and cream by stewed fruit and a light accompaniment would improve it.)
(d) Kidney soup; roast mutton, beans, potatoes; baked custard. (This meal is very high in protein. It would be improved by substituting a vegetable soup and having fruit instead of the custard.)

(e) Potato soup; beef steak pudding, potatoes, carrots; bread pudding. (In this meal, carbohydrate is in over-supply. A less starchy soup and pudding would improve it.)

2. Tea or Luncheon Menus

These are perhaps the most interesting meals to plan because there is such a variety of suitable dishes, e.g.

(a) For the main dish we may have fish, egg or cheese dish, salad, soup, soufflé, etc.
(b) The breadstuff may be varied, e.g. nut and raisin loaf, date loaf, scones (plain, sultana, cheese), gems, pikelets, and so on, are suitable for these meals and are usually popular with all members of the family.
(c) There may be a dessert or fresh raw fruit. Lunch is often the time when the daily raw fruit or vegetable may be served.
(d) Beverage may be tea, coffee, milk, cocoa, iced fruit drink.

EXERCISE Plan simple tea and luncheon menus for a day in summer and a day in winter.

3. Breakfast Menus

These may vary considerably in content, depending on the needs of the family, the season of the year, and so on. They may be:

(a) Light, consisting of fruit, cereal, bread (or toast), and a beverage.
(b) Medium, being the same as (a) plus a protein dish such as eggs, bacon, liver, etc.
(c) Heavy, being the same as (b) plus a vegetable such as potato, tomato, etc.

Variety is provided by the use of different types of cereal breakfast foods, fruits and vegetables, together with different ways of cooking eggs and other protein foods. The notes on the nutritive value of various types of cereal foods given in Chapter 23 should be kept in mind when planning breakfast menus.

EXERCISE Plan light, medium, and heavy breakfast menus for a day in summer and a day in winter.

THE COST OF MEALS

You should have some knowledge of the cost of common foodstuffs in order to be able to estimate the cost of the daily or weekly menu. It is important to know which foods are the most expensive, and where costs may be reduced by substituting foods of equivalent

nutritive value but lower cost. The prices of foodstuffs are continually changing, and those of the common foods should be collected by the class each year and a record made and kept up to date.

The amount of money that a family can spend on food varies according to the income of the family, the ages of the members of the family, and the amount of food that can be produced at home, e.g. vegetables, eggs, fruits.

It can be said that in New Zealand the amount of money spent on food is sufficient to keep the children in good health if it is spent wisely; but sometimes the importance of milk, fruits and vegetables is not realized, and the diet is low in these essentials. Even in 1948, the Annual Report of the New Zealand Department of Health stated: 'Sub-normal nutrition remains high. . . . Household dietary surveys reveal wrong feeding in too large a proportion of our homes—excessive carbohydrate or energy foods and insufficient protein or body-building foods and protectives.' It is a well-known fact that when the housewife has to economize, the amount of cereal products in the diet increases in proportion; but if these are to be fully used by the body, we have seen that it is essential to have generous amounts of milk and vegetables also. It is better to cut down on the meat intake than to sacrifice milk and vegetables to higher costs. Other points to be noted in choosing less expensive meals are:

1. Eggs are valuable but expensive foods. If milk is used in the full quantities recommended, the number of eggs used may be reduced.

2. Buy cheaper cuts of meat. These require more care in cooking than more expensive cuts; but their nutritive value is not inferior. Good use should be made of 'offals', too—liver, kidneys, tongues, etc.

3. Grow as many vegetables as possible. This is a great saving, and besides, the vegetables can be picked straight from the garden, and so will supply more vitamins than those bought in the shop or market. If this is not possible, full use should be made of the cheaper root vegetables and of the more plentiful and therefore cheaper kinds of green vegetables (e.g. cabbage instead of spinach).

4. Substitute peas, beans, and lentils sometimes for meat; but see that another of the day's meals contains a good first-class protein, such as cheese, for its main item.

SCHOOL LUNCH

Since the taking of lunch to school every day is a necessity for many children, the housewife should realize that the lunch forms a regular part of the child's food for the day. It should be looked upon in

this light, and not thought of as an 'extra' which is rather a nuisance to prepare in the rush of getting the members of the family off to work or to school. If the lunches are planned along with the family's meals for the week, their relation to the daily food will be more clearly realized.

A school lunch should,

(a) be appetizing, and

(b) supply about one-third of the recommended daily food requirements for children.

The following scheme is recommended by the Health Department for the planning of school lunches of good type:

1. *Sandwiches*, buttered—all wholemeal or half wholemeal and half white; *or* Rolls, buttered—preferably wholemeal.

2. *Fillings*. Two-thirds protein such as meat, eggs, cheese, fish, or peanut butter. With these may be included lettuce, cucumber, tomato, celery, or any other vegetable.
One-third sweet, such as dates, raisins, or black-currant jam.

3. No more than one buttered scone, gem, bun, or plain cake.

4. Milk, plain or flavoured, or milk shake. Unless provided at the school in addition to the mid-morning milk, a bottle of milk should be taken from home for lunch time.

5. Raw fruit or vegetable to finish, e.g. apple, orange, pear, banana, carrot, parsley, as well as those mentioned above.

Sandwiches usually form the main item of the lunch. These should be substantial—bread well buttered right to the edges and plenty of filling used. Unless sandwiches are made attractive they will often be thrown away. As well as the fillings mentioned above, ham, cottage cheese, peas, liver and nuts will provide first-class protein. When meat, bacon, etc. is taken at breakfast, or planned for the evening meal, the lunch need not contain much of this. Many other suitable fillings can be prepared, e.g. grated apple and raisin, banana and nut, sultanas, dates or any other dried fruit, chopped and mixed with lemon juice, fruit juice or salad dressing, and all sorts of salad greens.
Nut bread, date loaf, pikelets, and so on may be used instead of sandwiches, sometimes, or in addition when the lunch required is substantial. Iced cakes or sweets should not form part of the school lunch. Plain home-made cake such as madeira or gingerbread may be included occasionally. Dried fruits and nuts may themselves form valuable additions to the lunch and are popular forms of food for this meal.

Each type of food should be wrapped separately in greaseproof paper to keep the flavours from mixing and the items fresh. The whole should be packed in a lunch tin or other suitable container. In winter, unless something hot is provided at the school, soup, cocoa, etc. should be taken in a thermos flask.

Here are some examples of good types of lunches. As before mentioned, these should really be planned in relation to the other meals of the day and not as separate 'extras':

1. Wholemeal bread cheese sandwiches.
   Grated apple and raisin sandwich.
   Tomato (salt in paper).
2. Wholemeal bread egg sandwiches.
   Lettuce leaves.
   Home-made cookie.
   Carrot.
3. Cold fish and parsley sandwiches.
   Rolled oat shortbread.
   Peanuts.
   Pear.
4. Wholemeal scones.
   Lettuce leaves and tomato (salt in paper).
   Bran biscuits.
5. Marmite and nut sandwiches.
   Raisin bread.
   Banana.

In each case a milk drink, cold in summer, hot in winter, should also be provided.

EXERCISE

1. What rule can be regarded as basic, in meal planning?
2. What determines the amounts of supplementary energy foods needed by the various members of the family?
3. Why is variety an important consideration in a meal plan?
4. Give eight practical points to be followed in planning meals.
5. Discuss the planning of meals under such headings as cost, season, digestibility, colour and flavour, etc.
6. What three steps should be followed in building a menu for a family?
7. What are the main points to aim at, in planning school lunches, and how may these aims best be fulfilled?
8. Give two examples of a school lunch for yourself, (*a*) in summer, and (*b*) in winter. (Do not use the examples in the book.)

Appendix

A TERRARIUM

A TERRARIUM can be used in the laboratory to demonstrate different plant associations from swamp, grassland, forest, etc. and to study more closely the effect of plant and animal associations.

The terrarium case, if possible, should be of five to ten gallons capacity. A specially-built terrarium case has a slanting glass front, but an aquarium tank will serve admirably. The case should hold water if bog or swamp habitats are to be simulated. Place a glass cover over the case, so as to prevent draughts, or sudden changes in temperature, and to maintain an even humidity. A terrarium should reproduce the factors of the environment as near as possible. Do not mix plants and animals from entirely different environments. Factors to be watched very carefully are soil, water, amount of sun, humidity, shade, and overcrowding.

Frequent causes of failure of terraria are:

(1) Wrong type of soil, which does not allow air to circulate round the plant roots.

(2) Too much moisture, which promotes the growth of moulds. The glass cover should not be so close-fitting as to prevent the circulation of air. Remove the cover for a short period each day. Mould on plant stems may be treated by dusting with sulphur.

(3) Do not try to put more plants in the terrarium than are found in the natural habitat. Even then, because of absence of natural animal enemies, it may be necessary to trim some plants back or remove others.

PRESERVATION OF ANIMAL SPECIMENS

(Courtesy General Biological Supply House, Inc., Chicago)

	KILLING	FIXATIVE	PRESERVATIVE
Earthworms	(See dissection of the earthworm, p. 23)		
Crayfish	8% formalin or alcohol	8% formalin or 70% alcohol	8% formalin or 70% alcohol
Ticks and Mites	70% alcohol	70% alcohol	70% alcohol
Centipedes and Millipedes	Carl's solution	Carl's solution	Carl's solution
Insects: Dry	Carbon tetrachloride Killing jar		Mount in suitable boxes (cigar boxes) and pin out. Camphor placed in the box will help to keep museum pests away.
Insects: Wet	70% alcohol	Carl's solution	Carl's solution
Slugs and Snails	Anaesthetize in cooled boiled water* to which has been added enough tobacco to cover a threepence.	10% formalin	10% formalin
Starfish and Crustaceans	Anaesthetize in fresh water	10% formalin	10% formalin
Marine shellfish	10% formalin	10% formalin	10% formalin
Fishes	100% formalin	10% formalin	10% formalin
Frogs	Chloroform, or inject ether into the body	5% formalin	5% formalin

*The boiling drives out the air necessary for respiration.

NOTE: Large specimens such as fishes, frogs, and possibly some insects will need to have 10% formalin injected into the body cavity.

Carl's solution:		
	Alcohol 95% solution	170 cc
	Formalin	60 cc
	Glacial acetic acid	20 cc
	Water	280 cc

ANSWERS TO NUMERICAL PROBLEMS

Chapter 6

C *1.* 40
2. 80
3. 102
4. 40
5. 53·5
6. 138
7. 74
8. 685
9. 162
10. 162

D *1.* Mg = 60% O = 40%
2. S = 40% O = 60%
3. Al = 52·9% O = 47·1%
4. Na = 57·5% O = 40% H = 2·5%
5. N = 26·2% H = 7·5% Cl = 66·3%
6. K = 56·5% C = 8·7% O = 34·8%
7. Ca = 54% O = 43·2% H = 2·7%
8. Pb = 90·7% O = 9·3%
9. C = 44·4% H = 6·2% O = 49·4%
10. Ca = 24·7% H = 1·2% C = 14·8% O = 59·3%

E *1.* 25 lb
2. 9·25 g
3. 50 g
4. 21·7 cwt
5. 30·625 g

Chapter 12

1. 1. 7·8
2. 8·6
3. 2
4. 0·76
5. 40·8 g
6. 20·4 g
7. 100 lb
8. 1500 lb
9. 10 cc
10. 12 cc
11. 8 cu ft
12. 2 cu ft

2. 0·84; 8·4 lb
3. 2·5; 29·7 g
4. 6; (*a*) 40 g; (*b*) 41·6 g
5. 39 g; 1·5
6. 7
7. 0·8
8. 500 g
9. Yes
10. 71,680 cu ft
11. 50 g
12. 2 ft

Chapter 15

1. 5 cm; $166\frac{2}{3}$ g
2. 4·6 ft
3. 50 g
4. 72½ lb
5. 50 lb

Chapter 16

1. 1. 6 ohms; 96 watts
2. 44 ohms; 1100 watts
3. 5 amps; 150 watts
4. 5 amps; 550 watts
5. 120 volts; 960 watts
6. 6 volts; 9 watts
7. 3 amps; 4 ohms
8. 2 amps; 115 ohms

2. 36 volts
3. 4 amps
4. $76\frac{2}{3}$ ohms
5. 115 volts
6. 1. 16 ohms; 3 ohms
   2. 36 ohms; 5 ohms
   3. 48 ohms; 9 ohms
   4. 15 ohms; 3·6 ohms
7. 1. Series 0·75 amps Parallel 3 amps; 1 amp
   2. ,, 0·33 amps ,, 2 amps; 0·4 amps
   3. ,, 0·25 amps ,, 1 amp; 0·33 amps
   4. ,, 0·8 amps ,, 2 amps; 1·3 amps
8. 8·7 amps; 52·9 ohms
9. 2·17 amps; 4·35 amps; 8·7 amps
10. 6 ohms — 2 amps
    5 ohms — 1·6 amps
    20 ohms — 0·4 amps

Chapter 22

1. See p. 258
2. Object closer to the lens than *f*; enlarged, upright
3. (*a*) 12 cm; 1 cm; real
   (*b*) 16 cm; 2 cm; real
   (*c*) 24 cm; 4 cm; real
   (*d*) 24 cm; 8 cm; virtual
4. 200 mm
5. 4·5 in.
6. Convex f = 6 cm

Examination Papers

Questions in Chemistry, Physics, and Nutrition as set in the School Certificate examination papers over a period of ten years are presented in the following pages. It should be noted that only one paper is included for Section A (Biology), the reason being that this section was first introduced in 1956.

SECTION A

Biology 1956

1. (*a*) List five differences between photosynthesis and respiration.
   (*b*) State *briefly* what is meant by:
   (*i*) A rhizome;
   (*ii*) A pome;
   (*iii*) Defaecation;
   (*iv*) A xerophyte;
   (*v*) Fertilization.
   (*c*) Draw a diagram and label the various parts of the alimentary canal of any *named* mammal.

2. (*a*) List five functions of the blood system in mammals.
   (*b*) Draw a diagram of the apparatus that you could use to show that a plant transpires, and *briefly* describe the experiment.
   (*c*) Describe *briefly* how *one* modification of body structure in each of the following animals is related to the animal's particular way of life:
   (*i*) An earthworm;
   (*ii*) An insect;
   (*iii*) A fish;
   (*iv*) A frog;
   (*v*) A bird.

3. (*a*) Draw a diagram and describe briefly any experiment that you could do to demonstrate osmosis.
   (*b*) State *briefly* what is meant by:
   (*i*) Peristalsis;
   (*ii*) A control experiment;
   (*iii*) Anaerobic bacteria;
   (*iv*) Placenta.
   (*c*) Name three excretory products produced in a mammal and state which organs remove them.

4. *Briefly* describe any field study you have made under the following headings:
   (*i*) Measurements or observations of the local physical conditions.
   (*ii*) How any one plant or animal in the area studied is adapted to any of these conditions.
   (*iii*) Any other feature of your field study that has not been covered in the above.

SECTION B

Chemistry 1947

1. (*a*) By means of a fully-labelled diagram, illustrate the laboratory method for the preparation of nitric acid. (No written explanation required.)
   (*b*) State the uses of nitrates.
   (*c*) Describe your observations when a little concentrated nitric acid was added to copper turnings.

2. (*a*) Describe an experiment to show the effect of washing-soda on temporarily hard water. What conclusion can be drawn?
   (*b*) By what other methods could the same effect be obtained?
   (*c*) Account for the formation of a limestone cave.

3. (*a*) What materials would you use in the preparation of hydrochloric acid?
   (*b*) How could you then prepare chlorine from the hydrochloric acid?
   (*c*) Explain clearly the principle underlying this preparation of chlorine.
   (*d*) State two physical and two chemical properties of chlorine.

4. (*a*) Describe fully how you would prepare (*i*) a soluble salt, (*ii*) an insoluble salt. Name the substances used and the products formed in each case.
   (*b*) State (*i*) the properties of an acidic oxide, (*ii*) three commercial uses of sulphur.

5. Answer any five sections of this question. Describe the action of the following:
   (*i*) Sodium on water.
   (*ii*) Hydrogen on heated cupric oxide.
   (*iii*) Heat on calcium carbonate.
   (*iv*) Sulphur dioxide on a fresh, coloured flower.
   (*v*) The passage of an electric current through acidulated water.
   vi) Carbon dioxide on limewater.

Chemistry 1948

1. (*a*) Salts can be prepared by the action of—
   (*i*) An acid on a metal;
   (*ii*) an acid on a base;
   (*iii*) an acid on a carbonate;
   (*iv*) by double decomposition;
   (*v*) by direct union of a metal with a non-metal.

   Write down the following salts in a column, and, by writing the numbers (i), (ii), etc. alongside, indicate which of these methods you would employ (give one only for each) if you had to prepare a specimen of each.

   Write also, an equation for each reaction:

   a. Copper sulphate
   b. Silver chloride
   c. Ferrous sulphide
   d. Calcium chloride
   e. Copper nitrate
   f. Calcium carbonate

   (*b*) (*i*) By means of a fully-labelled diagram, show how you would prepare and collect a jar of hydrogen in the laboratory (no written description required).
   (*ii*) Write an equation for the reaction.

2. (*a*) Write down the formulae of the following:

(*i*) Dry Ice (Drikold)
(*ii*) Calcium bicarbonate
(*iii*) Washing-soda
(*iv*) Marble
(*v*) Sodium bicarbonate
(*vi*) Carbonic acid

Write down the following in a column, and, by using the letters (a), (b), (c), etc., referring to the above substances, name which of them you connect with each:

a. The cause of temporary hardness
b. Baking
c. Building material
d. Refrigerating material
e. Cleansing agent
f. Furring of kettles
g. Health salts
h. Aerated waters

(*b*) (*i*) Describe the changes which take place, and (*ii*) state how you would recognize the products, when each of the following compounds is heated in a test-tube:

a. Lead nitrate crystals
b. Copper sulphate crystals
c. Mercuric oxide

Give an equation for each action.

3. (*a*) Metals can be arranged into three categories, viz: (*i*) attack cold water; (*ii*) at high temperature, attack steam; (*iii*) even when heated, do not attack water or steam.

Arrange the following metals in a column, and write (i), (ii), (iii) to indicate to which each belongs:

Calcium	Magnesium	Zinc
Copper	Iron	Lead
Sodium	Potassium	Aluminium

(*b*) State, with brief notes, (*i*) two uses of ammonia; (*ii*) two uses of any of its compounds.

(*c*) (*i*) Describe what you would see when crystals of washing soda are exposed for a long time to the action of the atmosphere.

(*ii*) Explain the change observed in (*i*).

(*iii*) Describe what you would see, name the products formed, and write an equation for the reaction which takes place when zinc is added to copper sulphate solution.

4. (*a*) Which of the following are characteristics of metallic rather than of non-metallic elements?

(*i*) Low melting and low boiling points.
(*ii*) High specific gravity.
(*iii*) High lustre.
(*iv*) Brittleness.
(*v*) Ductility.
(*vi*) Yield at least one oxide with basic properties.
(*vii*) Yield oxides which are usually acidic.
(*viii*) Bad conductors of heat and electricity.
(*ix*) Often liberate hydrogen from dilute acids.

(*b*) Name an oxidizing agent and give one example of its use in the laboratory.

(*c*) State four characteristic properties of an acid solution.

Chemistry 1949

1. (*a*) (*i*) Draw a fully labelled diagram to show a laboratory method of preparing hydrochloric acid solution.

   (*ii*) Write the equation for the reaction.

   (*b*) Write down the numbers of the spaces in the following, and beside each number write the word necessary to complete the statements:

   Sulphur burns in air with a (1) flame, to form a (2, 3) called (4). This compound is used for (5) delicate fabrics and is (6) in water, forming an (7). This fact can be verified by adding neutral litmus, which turns (8).

   Most metallic oxides are (9); those which are soluble in water form (10). Most non-metals form (11) oxides, though a few, such as (12), form oxides neutral to litmus.

2. (*a*) Complete the following equations. (Write the whole equation in your answer):

   (*i*) $H_2SO_4 + CuO =$

   (*ii*) $HCl + KOH =$

   (*iii*) $AgNO_3 + NaCl =$

   (*iv*) $Zn + CuSO_4 =$

   (*v*) $CaCO_3$ (heated) $=$

   (*b*) (*i*) State—

   a. One cause of temporary hardness in water.

   b. The method of removal which applies *only* to this type of hardness.

   (*ii*) State briefly the action of sodium carbonate when added to

   a. permanently hard water,

   b. water used in the washing of greasy articles.

3. (*a*) Describe what you would see by (*i*) heating copper oxide with powdered charcoal, and (*ii*) passing the resulting gas into limewater.

   (*b*) Give an equation for reaction (*i*) and for reaction (*ii*), in each case stating the type of chemical change.

   (*c*) State, with brief notes, two commercial or industrial uses of (*i*) chlorine, (*ii*) hydrogen, (*iii*) nitrates.

4. (a) Describe what you would see and what would result if (*i*) a little water were added to a lump of quicklime in an evaporating dish, (*ii*) moist iron filings were left exposed to the air for some time, (*iii*) the teacher dropped a small piece of sodium into a dish of water.

   (*b*) (*i*) What do you understand by the term 'alloy'? (*ii*) State the composition of an alloy, and the purpose for which it is used.

Chemistry 1950

1. Make clear but not elaborate, labelled sketches of the apparatus used in your laboratory for the preparation of any four of the following: chlorine, nitric acid, oxygen, hydrogen, and carbon dioxide. Write the equations for the four preparations selected.

   Give one simple test you would use to identify each of the following gases: chlorine, hydrogen chloride, and carbon dioxide.

2 Describe the visible changes that take place and write the equations for each of the following reactions:

(*a*) Lead oxide is heated on a piece of charcoal by means of a blow pipe.

(*b*) Copper oxide is added to dilute sulphuric acid and warmed.

(*c*) Washing soda is added to permanently hard water.

(*d*) Calcium is dropped into water.

(*e*) Mercuric oxide is heated in a hard glass test-tube.

3. (*a*) Describe the commercial preparation of calcium oxide. Write the equation.

(*b*) Give two other common methods of preparing basic oxides. Illustrate each with an equation.

(*c*) Give two properties of basic oxides.

(*d*) Calcium oxide will react with water. Describe the reaction and give the equation. Give one use of the material produced.

4. (*a*) The following is a list of different types of chemical change. Give a common example of each with the equations:

(*i*) Combination
(*ii*) Decomposition
(*iii*) Replacement or substitution.
(*iv*) Double decomposition

(*b*) Select from the list of substances given below those which satisfy the following requirements:

(*i*) A common bleaching agent.

(*ii*) A yellow powder that burns in air with a blue flame.

(*iii*) An alloy used for the framework of aeroplanes.

(*iv*) A white crystalline solid that is obtained from sea-water.

(*v*) A substance used to soften hard water.

(*vi*) The acid present in vinegar.

Substances: Sodium sulphate, sulphur, citric acid, brass, sulphur dioxide, duralumin, sodium chloride, nitrogen, tartaric acid, sodium carbonate, acetic acid, copper sulphate.

Chemistry 1951

1. (*a*) Draw a sketch of any apparatus you have used to demonstrate the electrolysis of water. In your diagram indicate the positions of the positive and negative electrodes and the relative volumes of the gases evolved. How could you make the gases recombine to form water?

(*b*) Describe the visible changes which take place and name the principal substances which are formed in each of these reactions:

(*i*) Vinegar is added to washing soda.

(*ii*) Chile saltpetre is heated with concentrated sulphuric acid and the vapour condensed in a water-cooled flask.

(*iii*) Temporarily hard water is boiled.

(*c*) From what source or material are the following substances obtained commercially?

(*i*) Oxygen
(*ii*) Sulphur
(*iii*) Chlorine
(*iv*) Sodium Nitrate
(*v*) Tartaric acid
(*vi*) Citric Acid

2. (*a*) The following are some of the properties of hydrogen:
Smell—odourless. Appearance—colourless gas. Litmus—no action. Taper—the gas burns with a blue flame. Solubility—only slightly soluble in water.
Use the same headings to describe the properties of oxygen and chlorine.

(*b*) (*i*) Where is salt being extracted from sea-water in New Zealand?

(*ii*) What is added to salt to make 'iodized salt'?

(*iii*) Name any element or compound which is obtained commercially from common salt.

(*c*) (*i*) What percentage of sodium chloride is usually present in sea-water?

(*ii*) Some inland lakes and seas which lose water only by evaporation contain over 25 per cent of dissolved salts. Name one of these lakes or seas.

(*iii*) What is the impurity in common salt that causes it to become damp, especially in wet weather?

(*d*) With the aid of a diagram, describe briefly how you would determine the percentage of oxygen in a sample of air.

3. (*a*) Write brief notes on each of the following: Galvanized iron, tinplate, stainless steel, chromium-plated steel.

(*b*) Write down the two headings:

Acidic oxides Basic oxides

and after each write the appropriate compounds selected from the following list:

CaO, SO_2, PbO, MgO, SO_3, P_2O_5, ZnO, CO_2.

(*c*) Name a metal which (*i*) Reacts with cold water; (*ii*) reacts only when heated in steam; (*iii*) does not react with either water or steam.
Write equations to illustrate the reactions you select.

4. (*a*) (*i*) Draw a sketch of a simple soda acid type of fire-extinguisher and label the principal parts.

(*ii*) Write the equation for the reaction that takes place when the extinguisher is used.

(*iii*) What type of extinguisher is used for fighting oil fires? Why is ordinary water not satisfactory?

(*iv*) If an electrical switchboard were on fire, why must you never use a soda acid type of extinguisher or a hose to put it out? What is the best type of extinguisher for this purpose?

(*b*) What are the names of the following radicals or groups?

$= CO_3$, $NH_4 —$, $— NO_3$, $— OH$

Use any of the above to write the formula of (*i*) an acid, and (*ii*) a base.

(*c*) Write equations to illustrate *two* different types of reaction of each of the following: hydrochloric acid, sulphuric acid, nitric acid.

Chemistry 1952

1. (*a*) Write the chemical name and formula of each of the following compounds and give two common uses for each substance:

Bluestone, sal-ammoniac, slaked lime, caustic soda.

(*b*) Give four different types of physical change with an example of each. In what ways do they differ from chemical changes?

(*c*) Describe an experiment you have seen in which iron was used to displace hydrogen from water. In the diagram, indicate how the hydrogen was collected.

2. (*a*) With the aid of equations, outline the process by which nitric acid is manufactured from nitrogen, hydrogen, oxygen, and water.

(*b*) Explain what you understand by the terms 'oxidation' and 'reduction'. In the following equations, state which substance has been oxidized, and the name of the product it forms:

$$Mg + H_2O = MgO + H_2$$

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$$

(*c*) How would you prepare a solution of calcium bicarbonate? What visible changes would you observe when this liquid is (*i*) heated, and (*ii*) added to soap solution? Write equations for all reactions.

3. (*a*) Describe the manufacture of burnt lime and give four important uses of this substance.

(*b*) Give four standard methods of preparing basic oxides and illustrate each one with an equation.

(*c*) Describe how you would prepare a solution of hydrochloric acid from hydrogen chloride (hydrochloric acid gas). Draw a diagram to illustrate your method and mention any precautions which must be observed.

4. (*a*) Name two explosives and two nitrogenous fertilizers, and in each case state the raw materials from which they are manufactured.

(*b*) Write equations for the laboratory preparation of carbon dioxide, oxygen, ammonia, hydrogen, hydrochloric acid, sulphur dioxide, and nitric acid, and for the extraction of lead from lead oxide.

(*c*) How would you prepare in the laboratory samples of sodium sulphate, copper sulphate, and calcium sulphate?

Chemistry 1953

1. (*a*) What loss in weight would occur when 26 g of $Na_2CO_3 . 10\ H_2O$ is heated until it is converted to anhydrous sodium carbonate? (Atomic weights: Na = 23, C = 12, O = 16, H = 1.)

(*b*) A clear solution is thought to be dilute hydrochloric acid. Outline two chemical tests which, taken together, would enable you to confirm this. Give equations.

(*c*) How can limestone be converted to slaked lime? Give one important use of each of these substances. Give equations.

2. (*a*) Describe briefly how you would prepare a crystalline specimen of sodium nitrate starting with dilute nitric acid and any other necessary chemicals. (No diagram is required, but give equations.)

   (*b*) The sodium hydroxide reagent bottle in the laboratory is usually coated with a white powder. What is the substance, and how is it formed? Give equations.

   (*c*) What is an alloy? Give one example with its constituents. What advantage has the alloy you mention over the pure constituents?

3. (*a*) Draw a diagram of the apparatus used for the laboratory preparation of chlorine or dry ammonia. Label the parts and give equations.

   (*b*) Large quantities of rock phosphate and sulphur are imported into New Zealand each year. Explain, in not more than *ten lines*, for what purpose they are imported.

   (*c*) Give one example of each of the large-scale uses of:
   (*i*) Chlorine, (*ii*) ammonium sulphate, (*iii*) sodium carbonate crystals.

4. (*a*) Write equations for the following reactions:
   (*i*) Carbon and steam
   (*ii*) Calcium bicarbonate and calcium hydroxide
   (*iii*) Ferric oxide and carbon
   (*iv*) Hydrogen and chlorine

   (*b*) Each of the reactions in (*a*) is of great practical importance. Explain for what purpose.

   (*c*) Explain, in detail, how you would recover a pure sample of solid copper sulphate from a mixture of copper sulphate and sand.

Chemistry 1954

1. (*a*) Describe briefly how nitric acid may be obtained from sodium nitrate. Sketch the apparatus used for this purpose and write the equation.

   (*b*) A clear solution is thought to be dilute sulphuric acid. Outline two chemical tests which, taken together, would enable you to confirm this. Give equations.

   (*c*) What are the four main primary products from the destructive distillation of coal?

2. (*a*) Describe briefly how you would prepare a crystalline specimen of copper sulphate starting with dilute sulphuric acid and any other necessary chemicals. (No diagram required, but give equation.)

   (*b*) Air was passed through a strong solution of sodium hydroxide *A*, then through concentrated sulphuric acid *B*, then over hot copper *C*, and finally collected over mercury *D*. Describe the part that *A*, *B*, and *C* would play in this experiment. What gas would be collected in *D*?

   (*c*) Large quantities of lampblack, caustic soda, and sodium carbonate are imported into New Zealand each year. Write a short note explaining a major use to which each of these is put.

3. (*a*) Draw a diagram of the apparatus used in the laboratory for the preparation of a solution of hydrochloric acid. Label the parts and give the equation for the chemical reaction.

(*b*) Describe what you would see, name the products formed, and write equations for the reactions which take place when carbon dioxide is bubbled through limewater until no further change is apparent.

(*c*) Write a short note on the chief uses of:

(*i*) nitric acid, (*ii*) zinc, (*iii*) anhydrous ammonia.

4. (*a*) Write equations for the following reactions:

(*i*) Manganese dioxide is heated with concentrated hydrochloric acid.

(*ii*) Calcium hydroxide is neutralized with dilute hydrochloric acid.

(*iii*) Sodium carbonate solution is added to magnesium sulphate solution.

(*iv*) Carbon dioxide is passed over red-hot charcoal.

(*b*) In two of the above reactions oxidation and reduction occur. Name the two and state, in each case, which substance has been oxidized.

(*c*) Write a short note of explanation of the following terms and give one example for each: (*i*) acid salt, (*ii*) base, (*iii*) mixture, (*iv*) element.

Chemistry 1955

1. (*a*) Give briefly one reason for each of the following facts:

(*i*) White fumes appear when open bottles of hydrochloric acid and ammonium hydroxide are brought near each other.

(*ii*) Pure nitric acid is colourless, but in the laboratory it is usually brown.

(*iii*) Diamonds are used in rock drills.

(*iv*) Animal charcoal is used in sugar refining.

(*v*) Air is considered to be a mixture.

(*vi*) Litmus is used as an indicator.

(*b*) Sketch and label the apparatus used for the preparation of nitric acid. Give the equation for the reaction and the list of materials used.

(*c*) Give a common test for each of the following acids: dilute nitric, dilute sulphuric, dilute hydrochloric.

2. (a) Describe how you would convert magnesium carbonate into a crystalline specimen of magnesium sulphate. Give equation.

(*b*) Explain why—

(*i*) Health salts contain sodium bicarbonate;

(*ii*) Some stove polishes contain graphite;

(*iii*) Gunpowder contains potassium nitrate;

(*iv*) A little sulphuric acid is added to water which is to be electrolyzed.

(*c*) Give two important chemical and two important physical properties of ammonia. Give two important uses of ammonia.

3. (*a*) Explain what is meant by the following statements:

(*i*) The atomic weight of oxygen is 16.

(*ii*) Sodium hydroxide is deliquescent.

(*iii*) Carbon monoxide is a reducing agent.

(*iv*) Copper oxide is a base.

(*b*) Some metals can liberate hydrogen from cold water while others require to be heated in steam. Select one metal from each class and describe its action when liberating hydrogen from water or steam. Give equations.

(*c*) Explain briefly—

(*i*) What is galvanized iron?

(*ii*) Why is iron dipped in dilute acid before galvanizing?

(*iii*) Why is a blue flame often found burning on top of a coke fire?

4. (*a*) Write equations for the following reactions:

(*i*) Dilute sulphuric acid is added to magnesium.

(*ii*) Calcium hydroxide is neutralized with dilute sulphuric acid.

(*iii*) Sodium carbonate solution is added to calcium sulphate solution.

(*b*) Explain briefly—

(*i*) What is water gas?

(*ii*) How would you convert carbon dioxide to carbon monoxide?

(*iii*) How would you test for oxygen?

(*c*) Describe the experiments you would carry out to verify that—

(*i*) A given sample of drinking water contains dissolved solids;

(*ii*) A given white solid is quicklime;

(*iii*) A mixture of iron and sulphur has the properties of sulphur.

Chemistry 1956

1. (*a*) What is the loss in weight when 5 grams of crystalline copper sulphate $CuSO_4 \cdot 5H_2O$ are heated until all the water has been driven off?

Cu = 64 S = 32 O = 16 H = 1

(*b*) Draw a diagram of the apparatus for the laboratory preparation of dry ammonia. Label the parts and chemicals and give equation.

(*c*) State simply how each of the following is prepared:

(*i*) Water gas; (*ii*) Producer gas.

Give one main use for each.

2. (*a*) Copper (*i*) is ductile, (*ii*) resists corrosion, (*iii*) alloys with other metals Write a short note on the meaning of each property and give, in each case a use of copper which illustrates it.

(*b*) Write equations for the following reactions:

(*i*) Sodium carbonate is added to dilute hydrochloric acid.

(*ii*) Sodium bicarbonate is heated.

(*iii*) Steam is passed over red-hot iron.

(*iv*) Silver nitrate solution is added to sodium chloride solution.

(*v*) Calcium carbonate is heated strongly in a furnace.

(*c*) Describe briefly how you would convert sodium hydroxide solution into a crystalline specimen of sodium nitrate.

3. (*a*) Describe what you would observe when carbon dioxide is bubbled into limewater for a long time. Give equations.

(*b*) Write a brief note on the destructive distillation of coal and its economic importance to New Zealand.

(*c*) Explain what is meant by the following statements:

(*i*) Sodium bicarbonate is an acid salt.

(*ii*) Sodium hydroxide is an alkali.

(*iii*) Oxygen is obtained commercially from air by fractional distillation.

(*iv*) Calcium sulphate causes hardness of water.

4. (*a*) Describe fully an experiment to determine the percentage of oxygen in air. Draw a diagram of the apparatus used in this experiment.

(*b*) Give one reason why:

(*i*) The burning of magnesium in oxygen is regarded as a chemical change.

(*ii*) Sea water is considered to be a mixture.

(*iii*) A can half full of petrol is more dangerous than a full can of petrol.

(*iv*) Soda water goes flat when the bottle is opened and left to stand for some time.

(*v*) Blowing a candle flame puts it out.

(*c*) Describe what you would observe when:

(*i*) Sodium hydroxide solution is added to copper sulphate solution.

(*ii*) Water is added to quicklime.

(*iii*) Iron is warmed with dilute hydrochloric acid.

(*iv*) Hydrogen is passed over heated copper oxide.

SECTION C

Physics 1947

1. (*a*) By means of a diagram and a *short* explanation in each case, illustrate the meaning of any *two* of the following:

(*i*) The parallelogram law.

(*ii*) The moment of a force.

(*iii*) The mechanical advantage of a machine.

(*b*) (*i*) A candle flame 2 cm high is placed 5 cm in front of a plane mirror. Using a diagram to illustrate your answer, state:

a. Where the image will be seen, and its distance from the mirror.

b. The size of the image.

c. Whether the image is real or virtual.

(*ii*) If the same candle flame were placed 5 cm from the hole in a pin-hole camera, with the aid of a diagram, state:

a. The size of the image produced on a screen 10 cm from the hole.

b. Image upright or inverted.

c. Image real or virtual.

2. (*a*) Draw labelled diagrams to show the use of *one* of the following:
   (*i*) Any curved mirror.
   (*ii*) A simple microscope or magnifying glass.
   (*iii*) A glass prism to produce a spectrum.
   (*b*) Describe the construction of a simple voltaic cell and name two defects.
   (*c*) Find the horse-power of a wind mill that will pump 1650 lb of water to a height of 60 ft in two minutes (1 hp = 550 ft-lb per sec.)

3. (*a*) When a three-cell lead accumulator is fully charged, state:
   (*i*) Its voltage.
   (*ii*) How the hydrometer shows the state of charge of the battery.
   (*iii*) Whether its internal resistance is high or low.
   (*b*) How would you show the magnetic field due to two like magnetic poles situated a short distance apart? Illustrate by a diagram.
   (*c*) Describe the simplest and quickest method by which you would determine approximately the focal length of a double convex lens.
   (*d*) An empty specific gravity bottle weighs 40 grams; when full of water it weighs 240 grams. When filled with a liquid it weighs 206 grams. What is the specific gravity of the liquid?

4. (*a*) (*i*) State the principle of Archimedes.
   (*ii*) A balloon that weighs 600 lb when empty is inflated with 1600 lb of helium and displaces 3650 lb of air. How many pounds can it lift besides its own weight?
   (*b*) Describe an experiment you would perform in order to copper-plate a spoon. Illustrate by a fully-labelled diagram.

5. (*a*) The lighting of a room requires 250 candle-power and the lamps supplied require 0·8 watts per candle-power. Find the cost of lighting the room for twenty-four hours if the cost of supply is 5d per Board of Trade unit.
   (*b*) Draw a diagram of an electric bell, and explain the principle underlying the working of the bell.

6. Describe how to measure a resistance using an ammeter and a voltmeter. Illustrate by a circuit diagram.

Physics 1948

1. (*a*) A pin 2 cm long is placed upright and 2½ cm away from a vertical—
   (*i*) concave mirror of 8 cm radius of curvature;
   (*ii*) convex lens of 2 cm focal length.
   Draw diagrams to measurement (one for each) to show the position of the image formed by the mirror and the lens. In each case state:
   a. whether the image is real or virtual; b. whether the image is upright or inverted; c. the magnification.
   (*b*) A uniform metre rule with a 60-gram weight hanging from the 95 cm mark balances when supported at the 70 cm mark. What is the weight of the ruler?
   (*c*) Describe, with brief notes, a practical application of the principle of electrolysis.

2. (*a*) Explain how a heavy load may be lifted by means of a system of pulleys. Illustrate by a diagram. State the mechanical advantage.

(*b*) The current supply to a certain house is limited by a fuse wire to 5 amperes, and the voltage of the supply is 250:

(*i*) How many 100-watt lamps could be used at the same time?

(*ii*) Find the cost of lighting the maximum number of lamps for 10 hours if the price of electrical energy is 4d per B.O.T. unit.

(*c*) By means of a labelled diagram (no written description), show what happens when a ray of light passes through a triangular glass prism.

3. (*a*) (*i*) Draw a diagram to illustrate a simple form of dynamo.

(*ii*) Give an account of the principle governing the production of E.M.F.

(*iii*) What is the essential difference between a dynamo and a motor?

(*b*) A cubical tank of edge 2 ft internally is filled with a liquid of specific gravity 1·2. Find in pounds weight per square foot the pressure exerted by the liquid on the base of the tank. (Weight of 1 cubic foot of water = 62·5 lb.)

4. (*a*) By means of diagrams show:

(*i*) The optical system of a camera.

(*ii*) How short sight may be corrected by means of a suitable lens.

(*iii*) How to tell the polarity of a steel rod which is being magnetized electrically.

(*b*) A steel hammer weighs $2\frac{4}{9}$ tons. At each stroke it falls 3 yards:

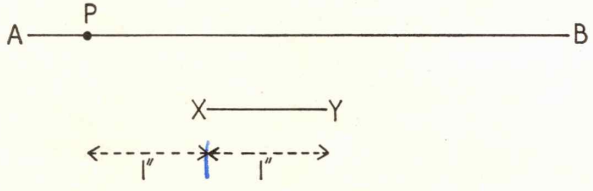
(*i*) How much work is done at each stroke?

(*ii*) If the hammer makes 30 strokes per minute, calculate the horse-power required to operate it. (1 hp = 550 ft-lb per second.)

Physics 1949

1. (*a*) (*i*) State the laws of reflection of light.

(*ii*) *P* is a point source of light on a horizontal surface *AB*. *XY* is a horizontal plane mirror placed as shown in the diagram. Draw rays of light to show that a patch of light 2 in long, and with one end vertically above *Y*, is formed on *AB*. Use your diagram to deduce the position, P^1, of the image of *P*. Is the image real or virtual?



(the head of the left-hand arrow is vertically beneath *P*)

(*b*) (*i*) State Ohm's Law.

(*ii*) A cable has a resistance of ½ an ohm per mile and is carrying a current of 40 amperes. What is the fall of potential in 22 yards of cable?

2. (*a*) A number of simple machines are designed to perform one of the following operations: (A) The lifting of weights or overcoming of resistances by the application of a relatively small force. (B) The movement of objects at a faster rate than that of the driving mechanism. Write down the following numbers, and beside each write the letter A or B to represent the particular function of the machine to which it refers.

(*i*) A crane
(*ii*) A windlass
(*iii*) A lawn-mower
(*iv*) A bicycle
(*v*) Nutcrackers
(*vi*) The brakes on a motor car
(*vii*) A treadle sewing-machine
(*viii*) A screw-jack
(*ix*) A hand egg-beater (rotating type)
(*x*) A nail-extractor.

(*b*) By means of a diagram, give an example of a practical use of a convex mirror, stating why it is used for this purpose in preference to any other type of mirror.

(*c*) A 3 kilowatt electric radiator is used on a 200 volt circuit. What is (*i*) the current flowing through it; (*ii*) the number of B.O.T. units of electricity used per week if the radiator is working each day at full power for 30 min, and at half power for 3 hours?

3. (*a*) What are the defects of a simple cell? How have these been overcome in a cell such as that used in a flash-lamp?

(*b*) (*i*) Calculate the least energy required by a boy weighing 10 st 3 lb to climb a flight of 24 steps, each of vertical height 8 in.

(*ii*) If he worked at the rate of $1\frac{3}{5}$ hp, how long would it take him to climb the steps?

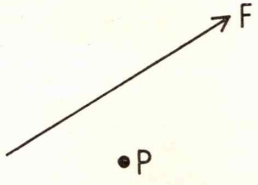
4. (*a*) (*i*) Name the pure metals (not alloys) which can be attracted by a magnet.

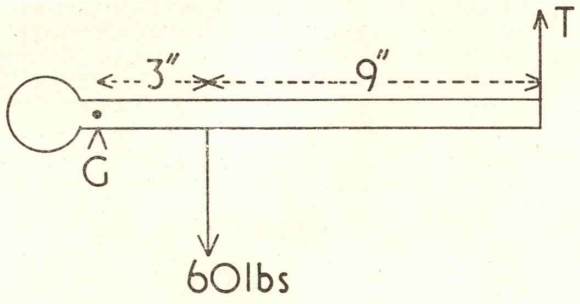
(*ii*) Describe what you consider the best method of testing for a magnet.

(*b*) (*i*) Draw a diagram to illustrate what is meant by the principal focus and the focal length of a convex lens.

(*ii*) What is the nature of the image formed when a convex lens is used as a magnifying glass?

(*iii*) By reference to the accompanying diagram, illustrate what is meant by the moment of a force about a point *P*.

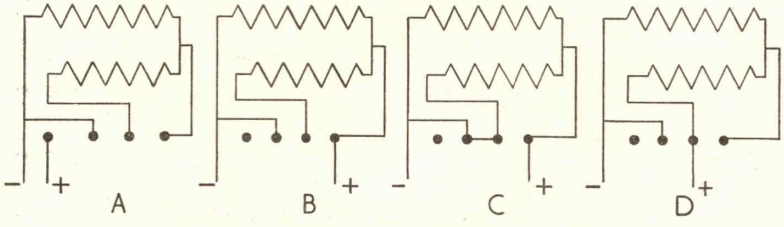




(*iv*) Calculate the tension *T*, if the bar is pivoted at its centre of gravity *G*, and is an equilibrium.

Physics 1950

1. (*a*)



The above diagrams show the connections for a three-heat control switch. On your paper, write down the letters A, B, C, and D, and after each state whether that circuit would give low, medium, high, or no heat when connected to the mains.

(*b*) Describe, with the aid of a diagram, how you would determine the position of the image in a plane mirror. Mark all equal angles and distances.

(*c*) If you were holding a wheel-barrow by the handles which were 3 ft 6 in from the axle, where would a 1 cwt block of iron have to be placed so that the total pressure exerted by your hands was 32 lb? (Disregard the weight of the barrow.)

2. (*a*) Make a sketch of a hydrometer. The markings on the stem go from 1000 to 2000. Show the approximate positions of these and the intermediate markings. To what mark would the hydrometer sink if placed in water?

(*b*) How would you make a simple secondary battery in the laboratory? During charging, what changes take place in—

(*i*) The colours of the plates?

(*ii*) The strength of the sulphuric acid?

(*c*) A barrel weighing 450 lb is hauled up a 12 ft plank onto a lorry 4 ft above road-level. If the pull is in a direction parallel to the plank, what force must be used?

3. (*a*) Make a sketch showing the relative size and position of the image that would be formed when a man is using a concave shaving-mirror.

(*b*) Describe briefly two methods you have used in the laboratory for determining the specific gravity of a piece of lead.

(*c*) A 1000-watt element is used on a 230-volt circuit:

(*i*) What current would pass through the element?

(*ii*) What would be the resistance of the element?

(*iii*) What length of wire having a resistance of 0·6 ohms per foot would be required to make the element?

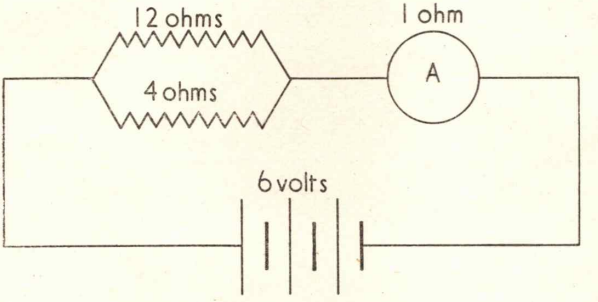
4. (*a*) Make simple sketches of (*i*) a common lift pump, and (*ii*) a force pump. In your diagrams, indicate clearly the positions of the valves and the directions in which they open.
To what height will each type raise water?

(*b*) Name the three methods by which heat travels and give an everyday example of each.
If two thermometers, one of which had its bulb painted black and the other its bulb painted white, were placed in front of an electric fire for a short time, would the readings on the two thermometers be the same? Give a reason for your answer.

(*c*) A raft 8 ft long, 5 ft wide, and 1 ft deep weighs 625 lb. To what depth will it sink in water?
What is the greatest weight that can be placed on it without causing it to sink? (1 cubic foot of water weighs 62½ lb.)

Physics 1951

1. (*a*) Draw in your manuscript book a graph which you could use for converting Fahrenheit readings between 32° and 212° into the corresponding temperatures on the Centigrade scale.



(*b*) From the information given in the above circuit diagram, calculate—

(*i*) The effective resistance in the circuit.

(*ii*) The reading on the meter.

(*iii*) The current flowing through the 12-ohm resistance.

(*c*) A 20-ton tank has stopped 10 ft from one end of a 40-ft bridge which weighs 50 tons. Use the principle of moments to determine the total downwards pressure on the supports at each end of the bridge.

(*d*) Make a sketch of a vertical section through a dry cell. Indicate the positions of the positive and negative terminals.

2. (*a*) Calculate the specific gravity of a solution of alcohol in water from the following data:

Weight of specific gravity bottle = 17 g

Weight of specific gravity bottle filled with water = 42 g

Weight of specific gravity bottle filled with dilute alcohol = 41 g

and use the table given below to determine the percentage of alcohol in the liquid:

S.G. of dil. alcohol	Per cent of alcohol by weight
0·99	4·6
0·98	11·3
0·97	18·9
0·96	26·1
0·95	32·2
0·94	37·5
0·93	42·5

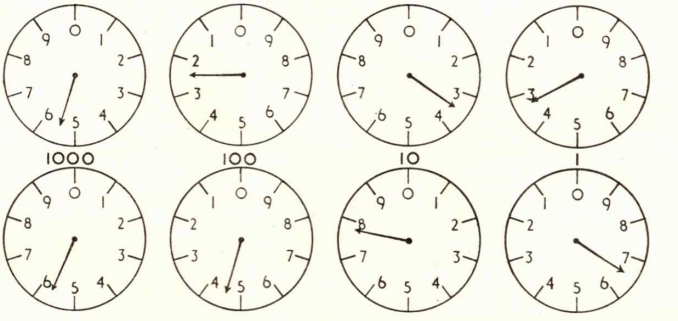
(*b*) Make sketches of the *three* orders of levers and give *one* everyday example of each type.

(*c*) Describe how you could use a compass needle to demonstrate that direct current is flowing in a piece of insulated copper wire. How could you determine the direction in which the current is flowing?

(*d*) Explain very briefly the difference between force and work.

3. (*a*) Two bar magnets are placed on a bench parallel to each other with their north poles pointing in the same direction and covered with a sheet of paper. Sketch the lines of force you would observe if iron filings were sprinkled on the paper.

(*b*) Describe, with the aid of a diagram, how you would determine the position of the focus of a concave mirror.



(*c*) The above are readings of an electric meter at the beginning and end of a particular month. If electricity is charged at the following rates, calculate the cost of electricity for this period:

First 20 units at 3d each,
Remainder at ½d each.

(*d*) A block of copper weighing 180 gm in air is suspended in a liquid by means of a fine wire. If the specific gravity of copper is 9, what will it weigh in (*i*) water, and (*ii*) a liquid with a specific gravity of 0·8?

4. (*a*) When a beam of white light passes through a glass prism it is broken up into a number of different colours. Make a sketch showing the path taken by the beam and the colours arranged in their correct order.

(*b*) If you were given some steel, soft iron, and zinc rods, how would you use their magnetic properties to identify the different metals?

(*c*) A block of wood 5 cm square and 4 cm thick floats in water so that 3 cm of its height is immersed. Calculate the weight of the block and the density of the wood.

(*d*) How would you make a simple mercury barometer in the laboratory? What is the normal height of the mercury column?

Physics 1952

1. (*a*) (*i*) By means of simple diagrams, show how you would connect up a resistance with a. an ammeter, and b. a voltmeter in order to increase the range of the instruments.
(*ii*) In a separate diagram, connect up these two instruments in a simple circuit.

(*b*) Describe how you would determine the density of tap-water. In your answer, indicate how you would calculate the result.

(*c*) A depth charge is set to explode when the pressure of the water becomes 80 lb per square inch. Calculate the depth at which this will take place in sea-water which has a density of 64 lb per cubic foot.

2. (a) Draw a diagrammatic sketch of a system of pulleys having a velocity ratio of 4. What is the mechanical advantage of this arrangement?

(*b*) How would you verify Ohm's Law experimentally?

(*c*) A piece of metal was found to weigh 95 grams in air, 83 grams in water, and 80 grams when immersed in a liquid. What is the specific gravity of the liquid?

3. (*a*) Draw a sketch of the Plimsoll line painted on the side of sea-going British ships. Place the letters FW, LR, S, WNA, and W opposite their appropriate lines and state what they stand for.

(*b*) Describe two experiments you have carried out to demonstrate the pressure of the atmosphere.

(*c*) A uniform rod 12 in long is suspended at a point 3 in from one end. If the rod balances when a 5 lb weight is placed at the end nearest to the fulcrum and a 1 lb weight at the other end, what is the weight of the rod?

4. (*a*) Draw a diagram of a camera and show how the light rays from a distant object pass through the lens and produce an image on the film. Mark the position of the focus.

(*b*) Describe three methods you could use to convert a piece of iron into a magnet. How would you determine which end is the N pole?

(*c*) What is the horse-power of an engine which can hoist 5 tons of coal up a mine-shaft 132 ft deep in four minutes?

Physics 1953

1. (*a*) Indicate what is meant by the moment of a force about a point and explain how the principle of moments may be investigated experimentally.

(*b*) Explain why the word PUN is read with difficulty when seen by reflection in a mirror whereas there is no difficulty with the word MUM.

(*c*) Explain why people whose faces are not symmetrical are commonly surprised at photographs of themselves whereas their friends claim the photographs are excellent likenesses.

(*d*) State Ohm's Law and find the current that will flow if a 2 volt cell is connected in series with a 10 ohm resistance and an ammeter of resistance 0·2 ohm.

2. (*a*) Describe, with a diagram, the construction and operation of one of the following forms of liquid pumps:

(*i*) a lift pump, (*ii*) a force pump, (*iii*) a gear pump.

(*b*) State briefly how you would show (*i*) the magnetic, (*ii*) the thermal, and (*iii*) the electrolytic effects of an electric current.

(*c*) Draw a ray diagram showing how a convex lens can be used as a simple magnifying glass. Label the relevant optical points.

3. (*a*) Describe how you would determine the focal length of a concave mirror by measurements of the distances from it to the object and to its corresponding image. What would be the focal length if the object distance was 20 cm and the corresponding image distance 10 cm?

(*b*) Calculate the cost of leaving a 60 watt electric lamp burning all night (twelve hours) when electricity costs ¾d a unit.

(*c*) Answer either (*i*) or (*ii*):

(*i*) A man, suspecting that his electric motor was defective, held the pulley belt with gloved hands while the motor was running at full speed (1400 rpm). He guessed that he was exerting a force of 10 lb wt when the motor began to slow down. What would be the horse-power actually produced if one turn of the pulley moved the belt 6 in?

(*ii*) Describe how you would determine experimentally the efficiency of any small pulley system of a commercial type. Calculate the efficiency of the system you describe using any reasonable numerical values.

4. (*a*) Calculate the greatest height in cm that water could be raised by a pump at a place on a mountain where the atmosphere pressure is equivalent to only 50 cm of mercury. (The S.G. of mercury is 13·6.)

(*b*) Describe one experiment involving or demonstrating the principle of Archimedes.

(*c*) The cupboard contains ammeters and voltmeters having ranges 0-15, 0-6, 0-2·5, 0-0·4, 0-0·15, 0-0·06 amps and volts respectively. Which would you select to measure the resistance of a small electric lamp which is nominally rated at 4 watts when running from a single accumulator cell?

Draw a suitable circuit diagram. Assume that the resistance of all of the ammeters is small but finite while that of all of the voltmeters is exceedingly great.

Physics 1954

1. (*a*) Describe briefly any one quantitative experiment or demonstration in mechanics or hydrostatics, indicating clearly what quantities were measured and how the final calculation was performed. Possible experiments might be: the principle of moments, the efficiency of a machine or an inclined plane, the density or S.G. of a liquid or of a solid.

   (*b*) Calculate the current taken by an electric lamp which is rated as 240 volts 60 watts, and find its resistance at its running temperature.

2. (*a*) A point object is slightly displaced from the principal axis of the single lens of a very simple form of camera. Draw a typical ray diagram, assuming that the object is at a reasonable distance from the lens other than infinity, and that the system is ideally focussed.
   Draw immediately underneath, a similar diagram on the same scale and for the same lens, showing the path of the rays when the object is too close to the camera to be correctly in focus.
   Indicate in both diagrams the position of the principal foci.

   (*b*) Calculate the pressure in lb per sq ft *or* in lb per sq in, in the water mains of a city if the city and the reservoir are respectively 100 and 350 ft above mean sea level. The density of water is 62·4 lb/cu ft.

   (*c*) Describe the action of any one practical device using the principle of electromagnetic induction. Possible items are: the magneto, the ignition coil of a motor car, a dynamo, a transformer. You may, however, describe any other device.

3. (*a*) Define *one* of the following and describe an experiment to evaluate it:
   (*i*) The specific heat of a substance.
   (*ii*) The latent heat of steam.
   (*iii*) The refractive index of glass.

   (*b*) Draw a diagram of an electric bell *or* of a telephone receiver (earphone) and explain its action.

4. (*a*) Give one instance where a knowledge of the principle of moments is likely to be of advantage in every-day life. Illustrate your answer with a typical numerical example.

   (*b*) It is proposed to fit a house with a press-button switch at the front door to ring an electric bell in the kitchen. There is available the following: Ample wire, a press-button switch, an electric bell labelled 3 volts, and four separate dry cells each labelled 1·5 volts. Draw a circuit diagram of the arrangement you would adopt to use *all* of these items.

   (*c*) Compare the advantages and disadvantages of the accumulator and the ordinary dry cell as a source of electrical current.

Physics 1955

1. (*a*) Describe how you would test the law of moments using a 50 g and a 100 g weight and a uniform metre stick, pivoted at its 40 cm mark and weighing 100 g. Show clearly the calculation involved in your method.

   (*b*) State whether you would prefer to use a dry cell or an accumulator for the following purposes and give your reasons:
   (*i*) For an electric door bell.

(*ii*) For showing, by means of iron filings or otherwise, the magnetic field associated with a long straight vertical wire carrying an electric current.

(*iii*) For experiments on measuring the heat produced by an electric current.

2. (*a*) Describe how you would find the focal length of a concave mirror *or* of a convex lens.

(*b*) Make a clear table showing which of the following phrases, used in dealing with heat transfer, should be attached to conduction, which to convection, and which to radiation. Indicate each phrase by its number, and do not copy it out. Some phrases may occur in more than one position.

(*i*) Travels in straight lines with the speed of light.

(*ii*) Does not warm the medium through which it passes.

(*iii*) Occurs in a vacuum.

(*iv*) Occurs in a fluid.

(*v*) Occurs in all solids.

(*vi*) The rate of heat transfer between two surfaces is proportional to the difference in temperature and decreases with the distance between them.

(*vii*) The rate of heat transfer increases with temperature very, very rapidly indeed at temperatures above red heat.

(*viii*) The rate of heat transfer is much reduced by polishing the surface.

(*ix*) The force making the medium move depends on the vertical height of the heated column and on the difference in temperature.

(*c*) The manufacturers of an electric clock claim that it uses only 1 Board of Trade unit of electricity every five days. Calculate its wattage and the current taken if it is to be used on 200 volt mains.

3. (*a*) Answer either (*i*) or (*ii*), but *not both*.

(*i*) Explain what is meant by work and calculate the maximum weight which can be lifted by a quarter horsepower motor if it is geared down so that it pulls the load upwards at a rate of 15 ft a minute. Neglect all friction and weight of the rope.

(*ii*) A boy makes a rectangular raft by lashing four empty 40 gal oil drums beneath a rectangular framework of wood. What would be the maximum load that the raft could carry when floating with the drums completely immersed, but with the wood just clear of the water? Each drum weighs 40 lb when empty and 440 lb when full of water and the weight of the wood frame is 100 lb.

(*b*) Describe with diagrams *two experiments* showing that light travels in straight lines. Your experiments might involve a pinhole camera or umbra and penumbra, or you may use any other method.

(*c*) Describe briefly some experiment you have seen on the electrolytic effects of an electric current.

4. (*a*) Sketch roughly a pulley system which can just lift a weight of 250 lb when a force of 50 lb is applied. Assume no friction and weightless tackle.

(*b*) Describe any two methods of determining the specific gravity of a piece of metal and state which method gives the more accurate result.

(*c*) How may iron filings maps of magnetic fields be obtained? Sketch the appearance of such maps when (*i*) two bar magnets are placed with their axes in a straight line and with the north poles near each other; (*ii*) as for (*i*) except that the north pole of one is near the south pole of the other. Neglect the presence of the earth's field.

Physics 1956

1. (*a*) By means of a clear diagram, show how you would arrange apparatus to demonstrate that light from an ordinary electric lamp is a mixture of different coloured lights. Show the passage of the beam of light through the apparatus. Give a reason for the result obtained.

(*b*) Use a sketch to show clearly how an electric current is produced in a bicycle generator.
What is the nature of this current?
Explain the expression: 'An electricity supply of frequency 50 cycles'.

(*c*) Account for the following:
(*i*) Lengths of pipe carrying hot water are sometimes looped in the middle.
(*ii*) Seaside districts usually experience less extremes of temperature than inland regions.

2. (a) State how the pressure in a fluid varies:
(*i*) With depth below the surface;
(*ii*) In different directions at the same depth.
Make use of the above facts to explain why:
(*iii*) A mountaineer can determine his altitude by means of a special type of barometer;
(*iv*) A barometer works just as well inside a house as out in the open.

(*b*) By means of a ray diagram, show how a lens may be used as a magnifier for examining stamps, etc. State the nature of the image produced.

(*c*) What is the temperature on the Fahrenheit scale of:
(*i*) Pure melting ice? (*ii*) '10 degrees of frost'?

(*d*) What is the effect on the boiling point of water of:
(*i*) Dissolving a quantity of salt in the water?
(*ii*) Allowing the pressure to rise by enclosing the water in a pressure cooker?

3. (*a*) You are required to find the resistance of a length of steel wire by the use of a voltmeter, an ammeter, a cell, and a suitable switch.
(*i*) Give the circuit diagram for this experiment.
(*ii*) What would be the resistance of the wire if the readings of the meters were 1·5 volts and 0·3 amp respectively?

(*b*) Explain:

(*i*) The control of the temperature of the body is assisted greatly by the presence of perspiration on the skin.

(*ii*) A nail becomes warm when it is being straightened by hammering on an anvil.

(*iii*) At what temperature has water a maximum density? How does this explain that when bathing, it is noticed that water at a depth in a pool is usually colder than that at the surface; yet during winter the water always freezes on the surface first?

(*c*) What is meant by the following statement:

The relative density of a piece of iron is 7·4?

(*d*) A stone, dropped from a high bridge, attains a velocity of 95·4 feet per second at the end of three seconds. What is its average acceleration?

4. (*a*) Use a large clear diagram, with notes, to explain the action of a relay. Give a common use for this device, referring to your diagram to indicate the necessary connections.

(*b*) 0·70 g of coal was burned in a vessel submerged in 750 g of water. The container, combustion vessel, etc. were equivalent to 110 g of water for heating purposes. The temperature rose from 18·4°C to 24·0°C. What was the heating value of the coal in calories per gram?

(*c*) Sunlight shines obliquely on to the smooth surface of a lake. Show clearly how the rays could travel:

(*i*) To the eye of a man on the bank, after reflection at the surface of the water;

(*ii*) To a fish at the bottom of the lake.

(*iii*) How do you decide on the path of the rays in case (*i*)?

(*iv*) Give the scientific name for the phenomenon in case (*ii*).

SECTION D

Nutrition 1947

1. (*a*) Explain the meaning of the term 'hydrolysis'.

(*b*) What part does hydrolysis play in (*i*) the digestion of starches, (*ii*) the fermentation of sucrose by yeast?

(*c*) Describe an experiment to illustrate one stage in the digestion of protein.

2. (*a*) Bearing in mind the Technical Commission's Recommendations and the present rationing system, plan a menu for one day in mid-winter for a family of two adults and two children, aged nine and twelve years.

(*b*) Outline the methods of preparation, cooking, and serving of the meals planned, so that the foods chosen will retain the greatest food value.

3. (*a*) Name the constituents of baking-powder, and state the function of each.

(*b*) Compare the action of baking-powder with that of yeast.

(*c*) Explain clearly the cleansing action of soap.

4. Write briefly on the following:

(*i*) The groups of foods to be included in a food parcel to England which would be most valuable in helping overcome present [1947] shortages.

(*ii*) The effect of rationing on the average sugar consumption of New Zealanders.

(*iii*) The value of skimmed milk as a food.

(*iv*) The refining of cereals and its effect on food values.

(*v*) The necessity for substitutes for oranges in the diet of infants.

5. Foods are treated, preliminary to despatch overseas, by the following methods. State clearly how each method is effective, and give, in each case, one example of a food which is so treated:

(*a*) Vacuum packing

(*b*) Dehydration

(*c*) Chilling

(*d*) Curing with salt

(*e*) Preserving with syrup

6. (*a*) Reproduce the table below, and fill in, using G to signify a good source and F to signify a fair source of the various food constituents:

	Energy	Protein	Calcium	Phosphorus	Vitamin D	Iron	Iodine	Vitamin A	Vitamin B_1	Vitamin B_2	Vitamin C
Whole milk											
Eggs											
Green vegetables											
Whole cereals											
Sugar											
Meat											
Cheese											

(*b*) What is the function in the body of (*i*) Vitamin D, (*ii*) iodine?

(*c*) State two of the richest sources of each of these dietary essentials.

Nutrition 1948

1. Compare and contrast the following menus, with special reference to:

(*a*) Their chief food constituents.

(*b*) Their respective nutritive value.

(*c*) Their appetizing quality.

(*d*) Their respective cost.

Menu 1	*Menu 2*
Roast Beef	Lentil Cutlets
Yorkshire Pudding	Mashed Potatoes
Baked Potatoes	Tinned Green Peas
Boiled Cabbage	Plain Suet Pudding
Gravy	Syrup Sauce
Apple Tart and Custard	

2. (*a*) (*i*) Explain what happens to the chief food constituent of: (a) white fish. (b) oatmeal porridge, as it passes down the alimentary canal of a mammal.

(*ii*) For each of these foods (fish and porridge), describe one simple test you could perform to show the nature of its chief constituent.

(*b*) (*i*) What organism is responsible for the production of alcohol during the making of bread?

(*ii*) From what substance is the alcohol produced during this process?

(*iii*) Would you expect the process to proceed most quickly in a cold, warm, or hot medium?

(*iv*) What compound besides alcohol is produced during this process?

(*v*) What is the term applied to chemical processes of which this is a typical example?

3. (*a*) (*i*) What is the value of iron in the diet?

(*ii*) Name three foods of different types which are rich sources of iron.

(*b*) Give a short account of—

(*i*) The scientific principles underlying the action of a pressure cooker.

(*ii*) The advantages of a pressure cooker.

(*c*) (*i*) What organism is mainly responsible for the souring of milk?

(*ii*) Explain the action of souring.

(*iii*) Describe one method of treatment which will check the activities of the organism.

4. (*a*) (*i*) What do you understand by the term 'protective foods'?

(*ii*) What daily quantity of each of these foods does the League of Nations Technical Commission recommend for a child of twelve to fourteen years?

(*b*) What precautions would you take in summer to preserve the freshness of the following foods in a larder: (*i*) Milk, (*ii*) fish?

(*c*) Give the general principles to be followed when (*i*) preparing, (*ii*) cooking, and (*iii*) serving an invalid's meals.

Nutrition 1949

1. (*a*) For each of the following foods, describe one test for its chief food constituent: (*i*) Top milk, (*ii*) lean meat, (*iii*) honey.

   (*b*) (*i*) What are the supplementary energy foods?

   (*ii*) What is their value in the human diet?

2. (*a*) State two methods by which each of the following foods may be preserved, and describe how each method is effective:

   (*i*) Fruits, such as peaches, apricots, or pears; (*ii*) fish.

   (*b*) Compare the food value of skimmed milk with that of whole milk.

3. (*a*) (*i*) State the chief protective food factor (a different one for each food) contained in each of the following foods:

   a. Cod-liver oil, b. iodized salt, c. oranges, d. fish.

   (*ii*) Write notes on its function in the body.

   (*b*) What precautions are necessary in the cooking of (*i*) starches, (*ii*) eggs, in order to ensure digestibility?

4. (*a*) What are the principles on which the following advice is given?

   (*i*) The Ministry of Food advises housewives to cook green vegetables quickly in a minimum amount of water, and to use the water in which they are cooked for making soups and gravies.

   (*ii*) By Board of Trade Regulations, persons who work under very hot conditions must be allowed adequate saline drinks.

   (*b*) State, with brief notes, the outstanding errors in the diet of the average New Zealander.

Nutrition 1950

1. The following menu has been planned for a boy 12-14 years of age:

   Breakfast: Toast, butter, honey, tea.

   Lunch: Jam sandwiches, buttered scones, tea.

   Dinner: Stewed chops, boiled carrots and potatoes, jam tart.

   (*a*) Show where the above menu is deficient in protective foods, vitamins, and the principal minerals.

   (*b*) Suggest changes where necessary in order to bring the day's menu up to the standard recommended by the League of Nations Technical Commission.

   (*c*) How much of each protective food is required daily by this boy?

2. (*a*) Describe with full experimental details how you would test for fat, protein, carbohydrate, calcium, phosphorus, and iron in a sample of milk.

   (*b*) If water has been added to milk, how is the amount determined?

   (*c*) What is the minimum percentage of butterfat permitted in (*i*) milk, and (*ii*) cream for domestic use?

3. (*a*) Give the name of one food with which each of the following preservatives may be effectively used:

(*i*) Acetic acid and vinegar
(*ii*) Sodium and potassium nitrates and nitrites
(*iii*) Salt
(*iv*) Spices
(*v*) Sugar
(*vi*) Wood smoke
(*vii*) Sulphur dioxide
(*viii*) Sodium benzoate

(*b*) Which of these preservatives are controlled by the New Zealand Food and Drug Regulations in the amount that may be used?

(*c*) Outline the principal methods employed for keeping apples, peas, and beans so that they may be available throughout the year. Mention any precautions that must be taken to preserve the vitamins and minerals while these foods are going through the preserving process and when they are undergoing subsequent cooking where necessary.

4. (*a*) Give an account of the raising agents used in cooking bread and cakes. In your answer, give equations where possible for the chemical actions that take place during the mixing of the ingredients and in the oven.

(*b*) What effect has cooking on (*i*) cane-sugar, and (*ii*) starch?

(*c*) How is icing-sugar manufactured?

Nutrition 1951

1. (*a*) (*i*) Describe the process of making dried apples and, in your answer, indicate the preservative that is used.

(*ii*) Explain why an aluminium preserving-pan cannot be used when removing the skins of peaches by dipping them in a boiling solution of sodium hydroxide.

(*b*) (*i*) Describe, with full experimental details, how you would determine the percentage of water in a sample of butter.

(*ii*) What other substance, in addition to water and butterfat, is present in butter?

(*c*) Give *four* rules for preparing and cooking vegetables.

2. (*a*) (*i*) Name the substances which are present in the *two* principal types of baking-powder on the New Zealand market.

(*ii*) Write the equations for the reactions that take place when water is added to each.

(*iii*) What effect, if any, has baking-powder on the vitamins which are present in the other ingredients of bread and cake?

(*b*) (*i*) What is the principal difference between first-class and second-class proteins?

(*ii*) What *type* of food usually contains second-class proteins?

(*iii*) When proteins are completely hydrolyzed, what compounds are formed?

(*iv*) Describe briefly how you would use the Biuret test to detect the presence of protein in a sample of meat.

(*c*) How would you make peanut butter?

3. (*a*) (*i*) How does the Health Department determine: (a) the percentage of butterfat, and (b) the presence of added water in a sample of milk?

(*ii*) Describe briefly the process for the pasteurization of milk.

(*iii*) Why does the Health Department recommend that milk should be pasteurized?

(*b*) Describe, with the aid of equations, the *chemical* changes that take place when yeast is added to dough.

(*c*) Name the food constituent that is deficient in the diet of a person suffering from (*i*) anaemia, (*ii*) rickets, (*iii*) beri-beri, (*iv*) scurvy), (*v*) goitre. In each case suggest a food which is rich in that constituent.

4. (*a*) (*i*) Copy the following table in your book and indicate a rich source with a '+' and a fair source with an 'O':

——	Carbo-hydrate	Pro-tein	Ca	P	Fe	Vitamins				
						A	B_1	B_2	C	D
White flour										
Wholemeal flour										

(*ii*) In New Zealand at the present time, what weight of white flour is extracted from 100 lb of wheat?

(*iii*) In order to shorten the time required for cooking, some breakfast foods are heated to a high temperature during the manufacturing process. Compare their nutritional value with that of porridge made from plain oatmeal.

(*b*) How would you extract some starch from a piece of raw potato? Give full experimental details.

(*c*) Describe very briefly how you would make a stew. In your answer explain why the meat must be placed in luke-warm salted water instead of boiling water.

Nutrition 1952

1. (*a*) Give four reasons why the Health Department considers it necessary to license and inspect public restaurants.

(*b*) You are supplied with samples of carrot juice, rose-hip syrup, and orange juice. Describe an experiment you could carry out to show which of these liquids is richest in vitamin C.

(*c*) We are advised to make greater use of tripe, liver, kidneys, and fish. For each of these foods, mention one aspect in which it is superior to flesh meats.

2. (*a*) Describe briefly how refined sugar is obtained from sugar-cane.

(*b*) How would you determine the percentage of mineral matter in a sample of wheat?

(*c*) (*i*) What changes should be made to cow's milk so that it will be suitable for infants?
(*ii*) Cow's milk is deficient in certain substances essential to the well-being of a baby. Name two of these substances and indicate how the two deficiencies can be remedied.

3. (*a*) Name four methods which are used for preserving eggs.
Describe one process which is used in the home and mention any precautions which should be taken.

(*b*) Describe how you would carry out an experiment to study the action of saliva on starch.

(*c*) What are protective foods and why are they important? What quantities of these substances does a child of three to five years require daily?

4. (*a*) Describe how tomatoes are preserved in the home. What precautions must be taken to conserve the vitamin C content?

(*b*) Describe the appearance of the liquids and state what are formed when olive oil is mixed with each of the following: (*i*) water, (*ii*) lime-water, (*iii*) solution of washing-soda, (*iv*) household ammonia, (*v*) boiling solution of sodium hydroxide, and (*vi*) ether.

(*c*) What are four of the principal recommendations of the League of Nations Commission with respect to diet?

Nutrition 1953

1. (*a*) What is a Calorie?

(*b*) If the edible portion of an egg, on the average, contains 13·4 per cent protein, 10·5 per cent fat, and no appreciable amount of carbohydrate, how many calories would 100 gm of egg provide?

(*c*) (*i*) What do you understand by the term 'protective food'?
(*ii*) Name six 'protective foods' and give the amount required daily by a twelve to fourteen-year-old girl.

2. (*a*) Quick-frozen fruits and vegetables are now available in many shops. What is the principle underlying this method of preservation? How do peas preserved by this process compare with the fresh produce for (*i*) quality, (*ii*) food value?

(*b*) Why does the Health Department urge the use of pasteurized milk?

(*c*) How is milk condensed? What is the principle underlying this method of preservation?

3. (*a*) How may starch be converted to (*i*) sugar, (*ii*) carbon dioxide and alcohol, (*iii*) carbon dioxide and water?

   (*b*) Copy the following table and fill it in concisely to show a routine test for each of the four chief food constituents:

Food Constituent	Reagents Used and Brief Description	Positive Result

4. (*a*) For what reasons is it desirable to cook meat?

   (*b*) Discuss scientifically the principles underlying the cooking of meat.

   (*c*) Explain how the best methods of preparing beef-tea conserve the more important constituents.

   (*d*) On heating, beef-tea separates into two parts: (1) A clear liquid, (2) a deposit of small brown particles. Name the food substances you would expect to be present in these two parts.

Nutrition 1954

1. The optimum diets for people of different ages, as recommended by the League of Nations Technical Commission, always contain milk, eggs, and green vegetables.

   (*a*) Why are these particular foods included?

   (*b*) Give the approximate percentage composition and a brief note on the food value of each of these foods.

2. (*a*) What causes deterioration in fresh foods when kept for more than the normal period of time?

   (*b*) List the general methods by which foods can be preserved, giving one example in each case.

   (*c*) Give the principles on which each of these methods of preserving depends.

3. (*a*) Name the three constituents of baking powder, and give the function of each constituent.

   (*b*) In some recipes, one of these constituents only is used together with other substitutes. Name four of these substitutes.

   (*c*) Writing your answer in tabular form, state the changes that occur in a loaf of yeast bread after it has been placed in the oven to bake.

4. On a winter's day a fourteen-year-old girl had the following meals:

Breakfast	*Mid-morning*	*Lunch*	*Dinner*
Oatmeal porridge with milk and sugar Toast and butter Tea	Buttered scone	Meat pie Cake chocolate	Vegetable soup Casserole steak Potato Spinach Carrot Creamed rice Prunes

Replan, where necessary, the above meals to provide for an adequate and well-balanced day's diet for this girl. Give reasons for your alterations.

Nutrition 1955

1. (a) Give the chief use in the body of (*i*) protein, (*ii*) carbohydrate, (*iii*) fat.

(*b*) Describe fully how you would apply one colour test to show the presence of (*i*) protein, (*ii*) peptone.

(*c*) Why are some proteins called first class and others second class? Give two examples of each of these classes.

(*d*) What is the name of the gas formed when protein is subjected to dry heat?

2. (a) Make a list of two rich sources of each of the following:
Vitamin A, vitamin B_1, nicotinic acid, vitamin C, iron and iodine.

(*b*) Write the name only of the disease caused by lack of each of the above food constituents.

(*c*) Give six rules to observe in the preparation, cooking, and serving of green vegetables to prevent loss of minerals and vitamins.

(*d*) Compare the vitamin content of—
(*i*) The inner and outer leaves of cabbage,
(*ii*) Cod liver oil and olive oil.

3. (*a*) Give reasons why foods are usually cooked.

(*b*) What is meant by the term hydrolysis? Give the products that result from the complete hydrolysis of protein, fat, and carbohydrate in the body.

(*c*) With full experimental details, explain how starch can be hydrolysed and the end product tested to prove its nature.

4. (*a*) Bearing in mind the recommendations of the League of Nations Technical Commission, list, with the approximate amounts in each case, the protective and supplementary energy foods an average active adult woman should have each day.

(*b*) Give the average percentage composition of pulses.

(*c*) Why are pulses of value in the diet?

(*d*) In a low-cost diet, what type of foodstuff can, to a certain extent, be replaced by pulses?

Nutrition 1956

1. (*a*) According to the League of Nations Technical Commission, how much of the following foods should a child five to seven years of age have daily?
Milk; meat, fish, or liver; sugar; green vegetable; cod liver oil.

(*b*) Write what you know of each of the following:
Basal metabolism, myosin, trypsin, endosperm, carotene.

2. (*a*) Of what elements are edible fats composed?

(*b*) List the chief properties of fats.

(*c*) How many Calories would be obtained from 15 grams of fat?

(*d*) Explain carefully the test you would carry out to ascertain if a given food contained fat.

(*e*) Explain the processes of digestion that a piece of white bread and butter undergoes from the time it is eaten until it is absorbed in the body.

3. (*a*) To what class of vegetables do potatoes belong?

(*b*) Name the two chief food substances in potatoes and give a chemical test for each.

(*c*) A family is without potatoes and unable to procure any. Plan (without giving amounts) dinners for three days in which potatoes are replaced by some other suitable food.

(*d*) Name the main food substance present in: peas (fresh), wholemeal flour, liver, walnuts (dried), cheese.

4. (*a*) Describe the conditions necessary for enzyme action.

(*b*) Give the *principles* underlying the preservation of food by:
(*i*) Bottling; (*ii*) Dehydration; (*iii*) Quick freezing.

(*c*) Describe one method by which milk can be preserved:
(*i*) Temporarily; (*ii*) For an indefinite period.

(*d*) Compare the food values of:
(*i*) Fresh and bottled green gooseberries.
(*ii*) Fresh and deep-frozen peas.
(*iii*) Cabbage raw (as in a salad) and cabbage cooked in a pressure cooker.

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